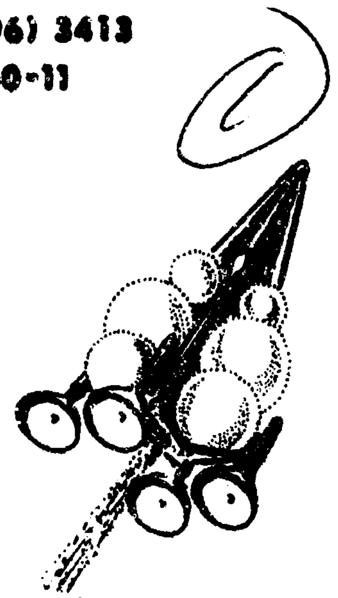
AD 710180

Contract AF 08 (606) 3413
AFMTC - TR 60-11



# MANUAL FOR HANDLING EXPLOSIVES, AMMUNITION AND SOLID PROPELLANTS

THERE IS NO OBJECTION TO PUBLIC RELEASE.
A. J. Wood
A. J. WOOD, Acting Chief Public Information Div.
OFFICE OF INFORMATION - AIR FORCE EASTERN TEST RANGE

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED. IT MAY BE RELEASED TO THE CLEARINGHOUSE, DEPARTMENT OF COMMERCE, FOR SALE TO THE GENERAL PUBLIC.





PAN AMERICAN WORLD AIRWAYS
GUIDED MISSILES RANGE DIVISION
PATRICK AIR FORCE BASE, FLORIDA

Prepared by Facilities Engineering Department

221

**Revisions to this MANUAL will be effected when additional data is made available and when circumstances warrant changes.**

**COPY NUMBER________**

TABLE OF CONTENTS

Contents

# INDEX OF TABLES, FIGURES AND FLOW SHEETS

## TABLES

## FIGURES

SECTION 1 Page

## FIGURES

SECTION 2 | Page

<u>FLOW SHEETS</u>

# FOREWORD......

Safety, relative to explosives, is chiefly dependent upon the degree of diligence exercised by those to whom their handling has been entrusted.

Many who have been closely associated with explosives are of the opinion that the conditions of storage largely determine the safety and efficiency that may be expected when explosive materials are used. Fires, explosions, emission of toxic gases, vapors, dusts, radiation, etcetera may result when the physical and chemical properties of stored materials are neglected. It is of prime importance for the safety of personnel and the protection of property that personnel engaged in explosive operations be cognizant of these properties and the hazards that may result from careless operations. It is of equal importance that all applicable Ordnance Regulations, Base Regulations and the recommendations of manufacturers be strictly complied with when explosive materials are assembled, transported, stored, destroyed or handled for any other purpose.

This MANUAL is not to be considered as a complete text in the field of explosives, ammunition and solid propellants, but rather an initial effort to combine some of this information into one volume. To this end, the suggestions and constructive criticisms of its readers will be welcomed and appreciated.

Acknowledgment is given to the many experts who have published their works in various government documents, books, etcetera; to those who contributed to the compilation, criticism and editing of this MANUAL; and to personnel of the Missile Propellants Section, Cape Canaveral Missile Test Annex of Pan American World Airways, Guided Missiles Range Division, for their cooperation and assistance in the publication of this MANUAL.

# PURPOSE......

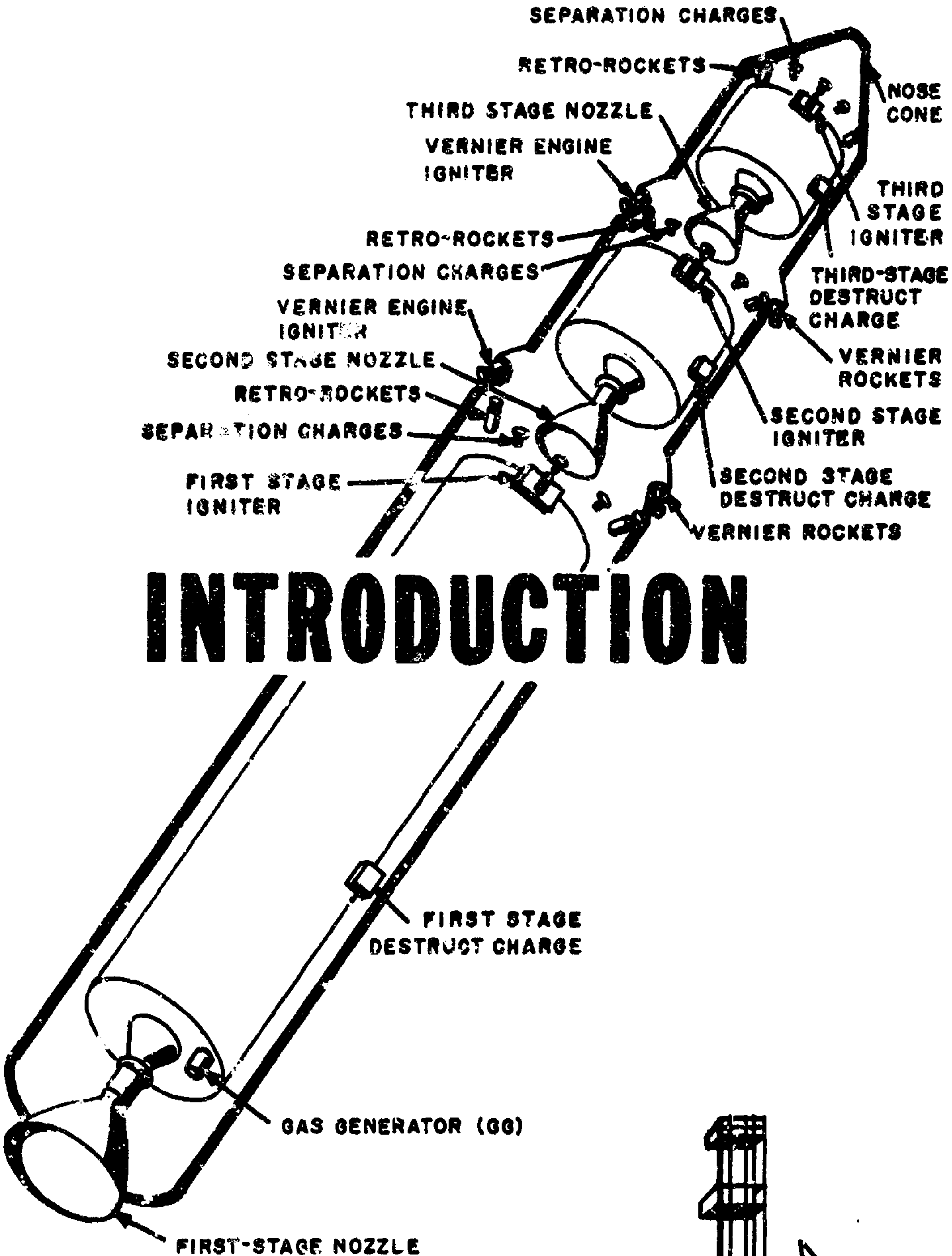
The purpose of ~~this~~ MANUAL is to provide a single source of general and technical information on explosives, ammunition and solid propellants. This MANUAL, which may be utilized as a reference or as an aid to instruction, presents a general description of the various items that contain explosive materials. Most of the items described are incorporated into the missile weapons systems prior to missile launching. The items described are hazardous to personnel when mishandled or improperly stored. Therefore, the general information presented indicates the safety measures necessary to receive, handle, store and transport explosives, ammunition and related accessories. These safety measures are not all inclusive, nor are they detailed, but when consolidated with local ground safety rules and common sense, will provide a means for obtaining safer operations with less hazard to personnel.

This MANUAL includes information abstracted from several sources and, therefore, is not to be considered as authoritative. However, the information does offer in a single source the description of explosive items used in the make-up of the majority of research and development missiles.

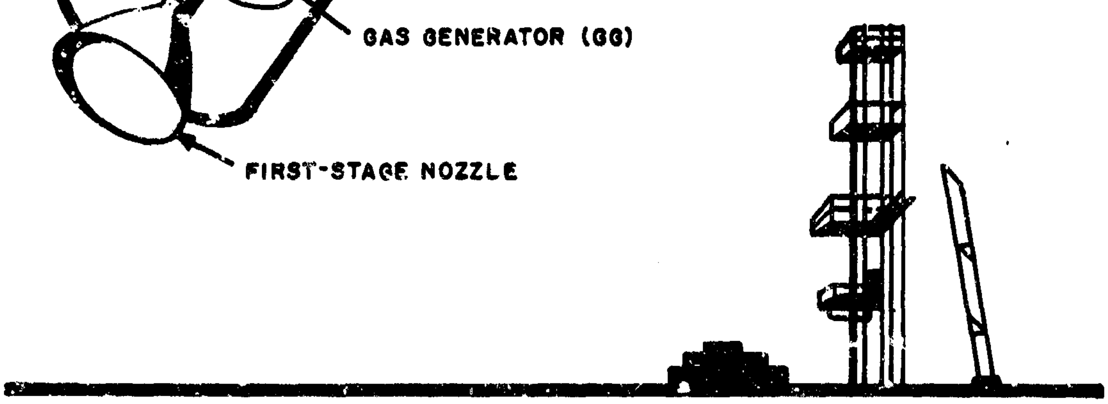
Most of the items described herein will possess the basic components listed but will be modified slightly to perform a prescribed function required in a particular missile.

The use of proprietary data and security information has been avoided. The use of this type data would necessarily classify this MANUAL and probably limit the distribution of the information.

PAN AMERICAN WORLD AIRWAYS
GUIDED MISSILES RANGE DIVISION
PATRICK AIR FORCE BASE, FLORIDA




# INTRODUCTION



Introduction to

# EXPLOSIVES, AMMUNITION AND SOLID PROPELLANTS MANUAL

The general descriptions of the explosives, ammunition and solid propellants in this MANUAL are written in a manner that does not conflict with military security regulations or encroach upon the proprietary rights of the missile contractors. However, this information is intended to present an overall description of the individual components received, stored and handled at the Pan American Solid Propellants Area at CCMTA. Continuity of text is partially lost as a result of describing the individual items.

A complete description of several explosive-ordnance items was not possible because of the meager data received from the manufacturer or fabricator. The lack of complete information preceding or accompanying new items has been a source of difficulty and concern to the personnel of the PAA Solid Propellants Unit. To assure greater personnel safety and operating efficiency in the Solid Propellants Area, complete and factual data pertaining to new explosive-ordnance devices must be transmitted to the supervision of this unit by the manufacturer in advance of the actual material shipment. Data that should be transmitted and which is necessary for safe operations should include classification, physical and chemical properties, degree and type of hazards and any special instructions concerning the handling and storage of specific items. This data will permit the operating personnel to become fully oriented in the methods of receiving, handling and storing new hazardous materials.

## TECHNICAL INFORMATION

The Technical Information includes definitions, a table of high explosive compositions, tables of initiating and non-initiating high explosives, equations of solid propellant rocket design and a table of typical solid propellant compositions. Also included is a table of the elements and their atomic weights and numbers. Tables of conversion factors and weights of materials complete the Technical Information.

## SECTION 1 - GENERAL INFORMATION

The General Information Section is divided into seven (7) subsections. These subsections are concerned with

classification, safety, protective clothing and equipment, packing and marking, transportation, storage, handling and destruction of explosives and ammunition.

Explosives and ammunition are classified according to type, chemical composition, function, storage and storage compatibility. They are also classified in accordance with shipping regulations, explosive and fire hazards and with the Department of Defense Security regulations.

Personnel safety, fire protection, care and precautions for handling explosives and ammunition are discussed. The general safety precautions presented in this MANUAL when combined with the local rules and regulations for safety can result in accident-free operations.

Methods for personnel protection against the hazards associated with explosives and ammunition are presented under the subsection entitled "Protective Clothing and Equipment." The personnel protective clothing and equipment consists of flameproof coveralls for the body, hard hats for the head, face shields for the face, goggles for the eyes, sound suppressors for the ears and conductive-sole shoes for the feet. Other protective equipment includes self-contained oxygen respirators, static electricity grounding-garters and a conductive shoe tester.

Rules and regulations regarding the transportation of explosives and ammunition by railroad, ship, aircraft and commercial and military trucks are presented.

Storage of Explosives and Ammunition presents a discussion of the Igloo-type magazines, fire symbols, inspection procedures and safety precautions necessary for storage.

The General Information Section concludes with the methods for the destruction of explosives and ammunition. Destruction is accomplished by burning, detonating or dumping at sea.

## SECTION 2 - EXPLOSIVES AND AMMUNITION

The Section on Explosives and Ammunition presents discussions of explosive trains, low explosives, solid propellants, pyrotechnics, high explosives, igniters, explosive-ordnance items, rocket motors and rocket accessories.

Various types of explosive trains are described and illustrated in this Section.

The discussion of low explosives describes black powder and squib compositions.

Solid Propellants are divided into single-base, double-base and composite propellants. Their uses, forms, burning actions and various compositions are presented.

The discussion of Pyrotechnic Compositions includes the compositions of pyrotechnic materials, their characteristics and uses.

The types and characteristics of High Explosives are presented for those explosives that are currently in military and commercial use.

The importance of the igniters to solid propellant rockets has prompted the writers to discuss the igniters separately from explosive-ordnance devices.

The Explosive Devices and Ordnance Items include a general description of the primers, squibs, detonators, boosters, explosive bolts, cartridges and valves, initiators, gas generators, explosive motors, destructors, safe and arming mechanisms, SOFAR bombs, staging and retro-rockets and non-explosive items that are used in fabricating a missile weapons system. Also, a brief paragraph of the hazards involved in handling explosive devices is presented.

Rockets and Rocket Motors presents a discussion of the component parts of the rockets and rocket motors.

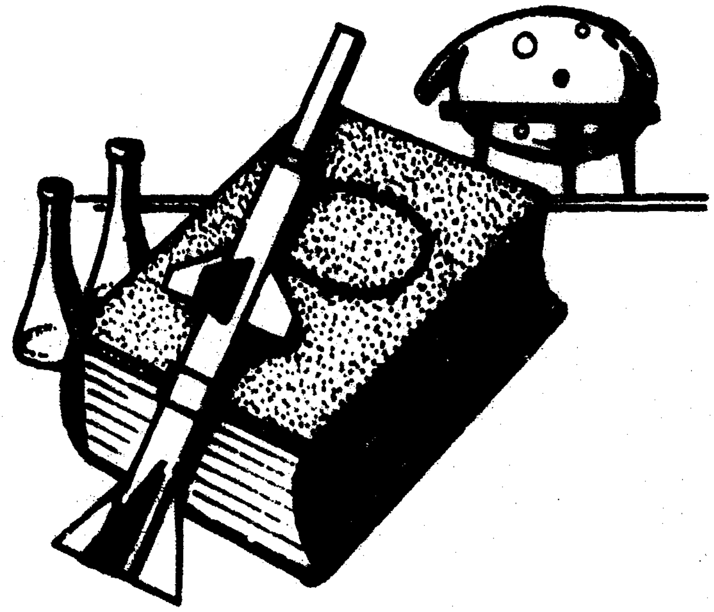
The hooks, rings, head plates, etcetera, used to complete the fabrication of a rocket are listed in Rocket Accessories.

## BIBLIOGRAPHY

Most of the information discussed in the MANUAL was extracted from the Air Force, Army and Navy publications listed in the Bibliography. Other information was taken from books written by authorities active in the rocket and missile industry.

PAN AMERICAN WORLD AIRWAYS
GUIDED MISSILES RANGE DIVISION
PATRICK AIR FORCE BASE, FLORIDA

# TECHNICAL INFORMATION



TECHNICAL INFORMATION

REVISION SHEET

1. Basic Communication February 1960

# DEFINITIONS

Ammunition

All the explosives and components in any case or contrivance prepared to form a charge, complete round or cartridge for cannon, howitzer, mortar or small-arms or for any other weapon, torpedo warhead, mine, bomb, depth charge, demolition charge, fuze, detonator, projectile, grenade, guided missile, rocket, etcetera. The term also includes all signaling and illuminating pyrotechnic materials and all chemical warfare materials.

Ballistic

Of or pertaining to ballistics (the art and science pertaining to the projection of missiles).

Ballistics, Exterior

Pertains to the laws governing the motion of projectiles and missiles in flight.

Ballistics, Interior

Concerned with the propulsion and launching of projectiles and missiles.

Barricade

(a) Natural

A natural barricade includes the natural features of the ground, such as hills and timber.

(b) Artificial

An artificial barricade is a mound or revetted wall of earth at least three (3) feet thick.

Blasting Cap

A small copper tube closed at one end and partially filled with fulminate of mercury or other detonating substances. They are used as primers to explode dynamite and other explosives. Blasting caps may be initiated electrically or mechanically.

Bomb

A receptacle, of any shape or size, containing an explosive material which is fired by concussion or by a time fuse.

Booster

(a) In a Missile Launching System

A vernacular term applied to an auxiliary propulsion system (booster motor, booster engine, booster rocket, booster rocket power plant or booster power plant) containing one or more attached or integrated (first stage) units that travels with the missile and which may or may not separate from the missile when its impulse has been delivered. The propulsion source may be either solid or liquid propellants.

(b) In Warheads

A high-explosive element sufficiently sensitive to be actuated by small-explosive elements in a fuze and powerful enough to cause detonation of the main explosive charge.

Brisance

The shattering power of explosives. It is a measure of the work that an explosive will accomplish and is usually dependent upon and indicated by the velocity of the explosive reaction.

Bursting Charge

Explosives characterized by being relatively insensitive and having high brisance or shattering power. Examples are TNT, picric acid and ammonium picrate.

Casting

Forming a plastic or liquid substance into a particular shape by pouring it into a mold and allowing it to cure. Cast-propellant grains are produced from single-base and double-base casting powders. Cast-composite propellants for JATOS and boosters are cast with a binder that frequently serves as fuel or oxidizing material. Composite propellants do not contain nitrocellulose or nitroglycerin.

Catalyst

A material that changes the rate of reaction without undergoing a final change.

Colloidal State

Refers to that state of a substance in which its particles are very fine, ranging from approximately 0.2 to 0.005 micron.

Component

A group of parts united to perform a certain function. A component is not self-sufficient but depends upon other components to accomplish a given task.

Composite

Made up of various parts. A composite propellant, often called heterogeneous, is composed of an oxidizing agent and reducing agent that occur in two (2) distinct phases. For example, it may merely be a mechanical mixture of finely powdered materials with a binding agent. Gunpowder is a composite propellant wherein potassium nitrate is the oxidizing agent, carbon is the reducing agent and sulfur is a combination of binder and reducing agent.

Corbetta Type Magazine

An earth-covered, reinforced concrete magazine (bee-hive, arch-shape dome or box type) used for storing explosives, ammunition and solid propellants.

Curing Accelerators

Substances that hasten the drying reaction in the process of manufacturing solid propellants. Examples of these substances include sulfur, flowers of sulfur, benzyl mercaptan, magnesium oxide and zinc oxide.

Deflagration

A slower form of detonation (see Detonation).

Deliquescent

A substance that dissolves gradually and becomes liquid by attracting and absorbing moisture from the air.

Depth Charge

An explosive projectile to be used against targets under water, especially submarines.

**Dermatitis**

Inflammation of the skin which is evidenced by itching, redness and various skin lesions.

**Destructor**

An explosive or other device used to intentionally destroy a missile or aircraft or a component thereof.

**Deterioration**

Implies impairment of vigor, usefulness, etcetera.

**Detonation (Explosion)**

An extremely rapid reaction, in which an oxidizer and a fuel combine with a great evolution of heat. A high-order detonation or "true detonation" proceeds with very high speed, generally several thousand feet per second. A low-order detonation is a partial or relatively slow explosion, generally caused by accidental or inadequate initiation. The term detonation should not be confused with deflagration, which may consume the same explosive materials but at a rate usually on the order of inches per second.

**Detonator**

A device used for exploding an explosive charge. It consists of a primer composition charge and one or more additional high explosive charges of different compositions. The charges are arranged in the order of decreasing sensitivity and increasing quantity.

**Diluents**

Diluting agents.

**Dynamite**

A mixture of nitroglycerin absorbed in a porous material. Dynamite is designated as a straight, ammonia, gelatin or ammonia-gelatin dynamite. It is generally prepared in paraffin coated one-half (1/2) pound sticks or cartridges, rated according to the per cent by weight of its nitroglycerin content.

**Exothermic**

A thermodynamic term descriptive of an evolution of heat or other energy.

## Explosive

An explosive includes any chemical compound or mixture of substances which, when subjected to flame, spark, heat, impact or friction will undergo extremely rapid to virtually instantaneous chemical and physical transformation.

Military explosives are divided into two classes, namely, high explosives and low explosives.

## Explosives, High

High explosives or detonating explosives are characterized by very high rates of reaction and high pressure. Examples of high explosives are TNT, dynamite and explosive D.

## Explosives, Low

Low explosives are mostly solid combustible materials that decompose rapidly but do not normally explode. This action is known as deflagration. Upon ignition and decomposition they develop large volumes of gases that produce enough pressure to propel a projectile or missile in a definite direction. Low explosives do not usually propagate a detonation. Under certain conditions they may react similar to high explosives; that is, they may detonate. Examples of low explosives are black powder and smokeless powder.

## Extrusion

The process of shaping a colloid by forcing it through dies by pressure.

## Fireworks

Devices that produce a striking display of light, noise or smoke by the combustion of explosive or inflammable compositions.

## Fuse

A slow burning device for transmitting a flame.

## Fuze

A relatively high speed device used to activate a warhead or explosive charge. It may operate at a specific time, on contact with or proximity to the target.

## Granulation

The process of forming or collecting into grains.

## Grenade

A grenade is an explosive or chemical device intended for use at relatively short range. Grenades are very effective for augmenting primary weapons. Smoke and tear gas grenades are effective for dispersing mobs, quelling riots, etcetera.

## Guided Missile

A guided missile is an unmanned vehicle designed as a weapon. It moves above the earth in a trajectory or flight path that may be altered either remotely or automatically by a mechanism within the missile. The missile destroys itself upon completion of its mission. In addition to control mechanisms, guided missiles include explosive warheads and power plants, usually rocket or jet type.

## Hermetically

Refers to a means of sealing containers so that they remain airtight or perfectly closed.

## Heterogeneous

Not alike; of different kinds. A composite propellant is heterogeneous because the oxidizing and reducing agents occur in separate, distinct phases.

## Homogeneous

Composed of similar parts. Colloidal propellants are homogeneous because the oxidizing and reducing agent is contained in a homogeneous or colloidal phase.

## Hygroscopicity

The tendency of a material to absorb moisture from its surroundings.

## Hypergolic Fuels

Rocket fuels or propellants consisting of combinations of fuels and oxidizers that spontaneously ignite when in contact with each other and achieve ignition temperature without outside assistance.

## Igniter

A device, usually electrical, that propagates the propellant charge to the ignition temperature and near operating combustion chamber pressure.

Ingredient

One of the parts of a mixture.

Integral Light

The overall light intensity in a required exposure time. This is one of the common characteristics o photoflash compositions.

Intraline Distance

The intraline distance is the distance to be maintained between any two (2) operating buildings and/or sites within an operating line, at least one of which contains or is designed to contain explosives. The distance from service magazines for the line to the nearest operating building shall be not less than the intraline separation required for the quantity of explosives contained in the service magazine.

JATO (Jet Assisted Take-Off)

A JATO is defined as an auxiliary rocket that can be attached to a vehicle for the purpose of applying thrust when needed. It is further defined as a complete, self-contained rocket unit that has a definite burning time and a fixed thrust. The word JATO has been adopted as the basic term for jet thrust units and includes boosters, sustainers and aircraft assist take-off devices.

Jute Bag

A glossy-fiber bag.

Kinetic Energy

The energy of motion.

Launch

To start with vigor; to hurl as a weapon; to throw.

Luminous

Bright, shining by its own light.

Mach Number

A number representing the ratio of the speed of a body to the speed of sound in the surrounding

atmosphere. For subsonic speeds the Mach number is less than one (1) and for supersonic speeds it is greater than one (1).

Oxidizer

A substance such as chlorate, perchlorate, permanganate, peroxide, nitrate, oxide, etcetera, that yields oxygen readily to support the combustion of organic matter, powdered metals and other flammable material.

Plasticizer

A material that is added to a propellant to increase its plasticity, work ability or to extend its physical properties.

Primers

Caps, tubes or wafers containing percussion powder or other compounds for igniting an explosive charge.

Projectile

A body projected by exterior force and continuing in motion by its own inertia. An object capable of being thrown or hurled.

Propellant

A substance which, either alone or in combination with another, supplies the mass of ejection for a rocket engine and the heat energy for conversion to kinetic energy in the exhaust jet. A propellant can be fuel, an oxidizer or a combination of both, in any physical state: solid, liquid, gas or plastic.

Propellant, Composite

See "Composite."

Propellant, Double-Base

A propellant consisting of nitrocellulose and nitroglycerin with the addition of certain stabilizers.

Propellant, Heterogeneous

See "Composite."

Propellant, Homogeneous or Colloidal

Homogeneous propellants are true monopropellants because each molecule contains the necessary fuel and oxidizer for combustion. Propellants containing nitrocellulose are examples of homogeneous or colloidal propellants.

Propellant, Restricted

A propellant system where combustion occurs perpendicular to the longitudinal axis of the grain ("cigarette" fashion). This type of propellant is often called an "end burner."

Propellant, Single-Base

A single-base propellant is composed of nitrocellulose with small quantities of modifying agents added for specific purposes.

Propellant, Unrestricted

A propellant system where combustion occurs on more than one planar surface.

Pyrotechnic

A mixture of an oxidizing and reducing agent designed to produce light, heat or perform some other nonpropulsive function.

Retardants

Substances that slow or retard a reaction as opposed to accelerators which speed-up a reaction.

Rocket

A missile propelled by the thrust caused by a discharging jet of gas from a burning propellant within the rocket. A self-propelled vehicle (non-air breathing) operating on the reaction principle.

Rocket Motor

A generic term for a solid propellant rocket consisting of the assembled propellant, case, ignition system, nozzle and appurtenances.

Sensitivity

A measure of the stability of a propellant to withstand heat and shock.

Squib

An electrical-pyrotechnic device used to ignite an explosive material, a primer or igniter.

Stabilizer

A material added to a propellant to suppress decomposition.

Sustainer

A propulsion system, that travels with and does not separate from the missile. The term is usually applied to solid propellant rocket motors that are used as the principal propulsion system as distinguished from auxiliary motors or boosters (JATOS).

Torpedo

A cigar-shaped projectile carrying a detonating charge. When the head of a torpedo strikes an object, a firing pin is driven against a percussion cap which explodes the charge.

## EXPLOSIVE COMPOSITIONS

| ITEM | COMPOSITION | USE |
|---|---|---|
| Ammanol | 67% TNT, 22% Ammonium nitrate, 11% aluminum | Bursting charge |
| Amatol | 50/50 60/40 80/20<br>TNT 50% 40% 20%<br>Ammonium Nitrate 50% 60% 80% | Bursting charge, Bangalore torpedoes |
| CBS | 85% RDX, 15% Desensitizer (oil) | Constituent of propellants |
| Composition A | 91% RDX, 9% beeswax | Bursting charge, high potential explosive, shell filler |
| Composition A3 | 91% RDX, 9% wax and wetting agent | Shell press loading |
| Composition B | 39.5% TNT, 59.5% RDX, 0.9% wax, 0.1% dispersing agent | High potential burster for shells and bombs |
| Composition B2 | 60% RDX, 40% TNT | Bursting charge in bombs |
| Composition C | 88% RDX, 12% plasticizing agent (oil base) | Plastic explosive, demolition, bursting charge |
| Composition C2 | 78% RDX, 22% plasticizing agent (MNT,DNT,TNT,XL-Solvent, NC) | Plastic explosive, demolition, shell filler (rockets) |
| Composition C3 | 78% RDX, 22% plasticizing agent (MNT,DNT,TNT,TET, NC) | Plastic explosive, demolition blocks |
| Composition C4 | 91% RDX, 9% plasticizing agent and binder | Plastic explosive, high potential bursting charge |
| Composition D2 | 13% nitrocellulose, 85% wax, 2% lecithin | Desensitizing agent |
| Cyclotol | 25/75 40/60<br>TNT 25% 40%<br>RDX 75% 60% | Adapter booster, bursting charge |

EXPLOSIVE COMPOSITIONS (Continued)

| ITEM | COMPOSITION | USE |
|---|---|---|
| DBX | 40% TNT, 42% RDX-$NH_4NO_3$, 18% aluminum | High explosive |
| EDNATOL | 57/43 60/40 55/45 50/50<br>EDNA 57% 60% 55% 50%<br>TNT 43% 40% 45% 50% | Bursting charge |
| HBX | 38% TNT, 40% RDX, 17% aluminum, 5% desensitizer | Warhead |
| Minol | 40% TNT, 40% $NH_4NO_3$, 20% aluminum | Burster charge |
| Pentolite | 10/90 30/70 40/60 50/50<br>PETN 10% 30% 40% 50%<br>TNT 90% 70% 60% 50% | 30% to 75% PETN-pentolite in bursting charge, 10% PETN pentolite in fuze and boosters |
| PEP-2 | 85% PETN, 15% desensitizer (oil) | Demolition |
| PEP-3 | 85% PETN, 15% desensitizer (oil) | Demolition |
| PIPE | 81% PETN, 19% desensitizer (oil) | Demolition |
| Picratol | 52% Explosive D, 48% TNT | Armor-piercing projectiles |
| PTX-1 | 20% TNT, 30% RDX, 50% tetryl | Mines, demolition |
| PTX-2 | 28% TNT, 44% RDX, 28% TNT | Shaped charges, shell |
| RIFE | 85% RDX, 15% desensitizer (oil) | Demolition |
| Tetrytol | 70/30 80/20 75/25 65/35<br>Tetryl 70% 80% 75% 65%<br>TNT 30% 20% 25% 35% | Bursters, demolition blocks, destructors |
| Torpex | 40% TNT, 42% RDX, 18% aluminum | Bursting charges for underwater use |
| Torpex #2 | 12% TNT, 70% Comp. B, 18% aluminum | |
| Torpex #3 | 99.5% Torpex #2, 0.5% $CaCl_2$ | |

EXPLOSIVE COMPOSITIONS (Continued)

| ITEM | COMPOSITION | USE |
|---|---|---|
| Tridite | 80% picric acid, 20% dinitrophenol | TNT substitute |
| Trimonite | 88% picric acid, 12% a-mononitronaphthalene | TNT substitute |
| Tritonal | 20/80 30/70 40/60<br>Aluminum 20% 30% 40%<br>TNT 80% 70% 60% | Bursting charge in bombs |

## INITIAL DETONATING AGENTS

| ITEM | OTHER NAMES | USE |
|---|---|---|
| Diazodinitrophenol | 4, 6, dinitrobenzene - 2- diazo - 1 - oxide, dinol, diazol or DDNP | Blasting caps, primary compositions and detonators |
| Lead Azide | Dextrinated Lead Azide, Orthorhombic (Alpha) lead azide or monoclinic (beta) lead azide | Initiating agent for high explosives |
| Lead Styphnate | 2, 4, 6 - trinitroresorcinate | Igniting charge for lead azide and ingredient in primary compositions |
| Mercury Fulminate | $Hg\ (ONC)_2$ | Detonators, an ingredient in priming compositions and blasting caps |
| Tetracene | 4-guanyl - 1 - (Nitrosoaminoguanyl) - 1 - tetracene | An ingredient of priming compositions |

## NON-INITIATING HIGH EXPLOSIVES

| ITEM | OTHER NAMES | USE |
|---|---|---|
| Ammonium Nitrate | $NH_4$ $NO_3$ | Oxidizing agent in propellants and explosives |
| Explosive "D" | Ammonium 2,4,6,-trinitrophenolate, ammonium picrate | Armor-piercing projectiles, ingredients of picratol and used in propellant compositions |
| Haleite | Ethylenedinitramine, N,N[1]-dinitroethylenediamine or EDNA | High potential explosive, burster charge and booster |
| Nitrocellulose | Cellulose nitrate, NC, pyroxylin, collodion, pyrocellulose or guncotton | Manufacture of nitrocellulose propellants and smokeless powders |
| Nitroglycerin | Glyceryl trinitrate or NG | Smokeless powders, solid propellants and minute amounts for medicinal purposes |
| Nitroguanidine | Picrite or guanyl nitramine | Smokeless and flashless propellants |
| Nitrostarch | Starch nitrate or xylidine | Commercial blasting explosives, bursting charge for grenades and mortar shells |
| PETN | Pentaerythrite tetranitrate, penta, pentrit or nitropentaerythrite | Detonating fuze and boosters, priming compositions, blasting caps and detonators |
| Picric Acid | 2,4,6-trinitrophenol, melinite, lyddite, pertite or shimose | Manufacturing of Explosive "D" |
| RDX | Cyclotrimethylenetrinitramine, hexahydro- 1,3,5- trinitro-5-triazine, cyclonite, hexogen or T4 | Base charge for detonators and as an explosive for shells and bombs |

NON-INITIATING HIGH EXPLOSIVES (Continued)

| ITEM | OTHER NAMES | USE |
|---|---|---|
| Tetryl | 2,4,6- trinitrophenyl-methylnitramine, tetralite, pyronite or CE | Booster, ingredient in binary explosive, detonators and blasting caps |
| TNT | Trinitrotoluene alpha or 2,4,6- trinitrotoluene, trotyl, tolite, triton, tritol or trilite | Most important bursting explosive, used as an ingredient of binary explosives in shells, bombs, grenades, demolition explosives and propellant compositions |

## SOLID ROCKET DESIGN EQUATIONS

### SPECIFIC IMPULSE

$$I_{sp} = \frac{F}{\dot{W}} = \frac{F\Delta t}{W_p} = \frac{c^* C_f}{g} = \frac{V_j}{g} = \frac{C_f}{C_w}$$

### TOTAL IMPULSE

$$I = Ft \text{ (for constant } F) = W_p I_{sp}$$

### OVER-ALL IMPULSE

$$I_o = \frac{Ft}{W_o}$$

### CHARACTERISTIC VELOCITY

$$c^* = \frac{I_{sp}\, g}{C_f} = \frac{g}{\dot{W}} p_c A_t = \frac{g}{C_W} = \frac{V_j}{C_f}$$

### EXHAUST VELOCITY

$$V_j = g I_{sp}$$

### WEIGHT FLOW

$$\dot{W} = A_p \gamma_p p_c a_2 = r_o A_p \gamma_p = C_w p_c A_t$$

### THRUST COEFFICIENT

$$C_f = \frac{F}{p_c A_t} = \frac{V_j}{c^*}$$

# SOLID ROCKET DESIGN EQUATIONS Cont'd

## WEIGHT FLOW COEFFICIENT

$$C_w = \frac{\dot{w}}{p_c A_t}$$

## LINEAR BURNING RATE

$$r_0 = a_2 p_c^n \equiv \frac{\dot{w}}{A_p \gamma_p}$$

## AREA RATIO

$$K_n = \frac{A_p}{A_t} = \frac{c_w p_c^{1-n}}{a_2 \gamma_p}$$

## CHAMBER PRESSURE

$$p_c = \left( \frac{K_n a_2 \lambda_p'}{C_w} \right)^{\frac{1}{1-n}}$$

## IMPULSE-WEIGHT RATIO

$$R_{I/W} = \frac{I}{W_0}$$

## PRESSURE SENSITIVITY TO TEMPERATURE

$$\Phi_p = \frac{(\Delta n)(p_c)}{\Delta T}$$

## THRUST

$$\frac{\dot{w} V_j}{g} = \frac{P_c A_t I_{sp}}{C^*} = P_c A_t C_f$$

LEGEND

| | | |
|---|---|---|
| $a_2$ | = | EXPERIMENTAL CONSTANT |
| $A_p$ | = | BURNING SURFACE, SQUARE INCH |
| $A_t$ | = | NOZZLE THROAT AREA, SQUARE INCH |
| $c^*$ | = | CHARACTERISTIC VELOCITY, FPS |
| $c_w$ | = | WEIGHT FLOW COEFFICIENT |
| $C_f$ | = | THRUST COEFFICIENT |
| $F$ | = | THRUST, LB. |
| $g$ | = | ACCELERATION OF GRAVITY, $FPS^2$ |
| $I$ | = | TOTAL IMPULSE (lb. sec. $= F\Delta t = W_p I_{sp}$) |
| $I_o$ | = | OVER-ALL IMPULSE, lb sec/lb |
| $I_{sp}$ | = | SPECIFIC IMPULSE, lb sec/lb |
| $K_n$ | = | AREA RATIO |
| $n$ | = | EXPONENT OF BURNING RATE, USUALLY BETWEEN 0.4 AND 0.8 |
| $P_c$ | = | CHAMBER PRESSURE, psi |
| $r_o$ | = | LINEAR BURNING RATE, in./sec |
| $R$ | = | GAS CONSTANT, 1545 ft/$^oR$ |
| $R_{I/W}$ | = | IMPULSE WEIGHT RATIO |
| $t$ | = | TIME, sec |
| $T$ | = | TEMPERATURE, deg F |
| $V_j$ | = | EXHAUST JET VELOCITY, FPS |
| $\dot{W}$ | = | WEIGHT FLOW OR RATE OF PROPELLANT, lb/sec |
| wo | = | WEIGHT OF OXIDIZER |
| $W_o$ | = | OVER-ALL WEIGHT, lb |
| $W_p$ | = | PROPELLANT WEIGHT, lb |
| $\gamma_p$ | = | SPECIFIC WEIGHT OF PROPELLANT, lb/cu in. |
| $\gamma_p'$ | = | $\gamma_p - \gamma_g$ = DIFFERENCE IN SPECIFIC WEIGHT OF THE PROPELLANT AND THE GASES IN THE FREE VOLUME OF THE COMBUSTION CHAMBER, lb/cu in |
| $\emptyset p$ | = | PRESSURE SENSITIVITY TO TEMPERATURE, per cent/deg F |

# INTERNATIONAL ATOMIC WEIGHTS, 1959*

| ELEMENTS | SYMBOL | ATOMIC WEIGHTS | ATOMIC NUMBER | VALENCE |
|---|---|---|---|---|
| Actinium | Ac | 227.0 | 89 | - - - |
| Aluminum | Al | 26.98 | 13 | 3 |
| Americium | Am | 243.0 | 95 | 3, 4. 5, 6 |
| Antimony | Sb | 121.76 | 51 | 3, 5 |
| Argon | Ar | 39.944 | 18 | 0 |
| Arsenic | As | 74.92 | 33 | 3, 5 |
| Astatine | At | 210.0 | 85 | 1, 3, 5, 7 |
| Barium | Ba | 137.36 | 56 | 2 |
| Berkelium | Bk | 249.0 | 97 | 3, 4 |
| Beryllium | Be | 9.13 | 4 | 2 |
| Bismuth | Bi | 209.00 | 83 | 3, 5 |
| Boron | B | 10.82 | 5 | 3 |
| Bromine | Br | 79.916 | 35 | 1, 3, 5, 7 |
| Cadmium | Cd | 112.41 | 48 | 2 |
| Calcium | Ca | 40.08 | 20 | 2 |
| Californium | Cf | 251.0 | 98 | - - - |
| Carbon | C | 12.011 | 6 | 2, 4 |
| Cerium | Ce | 140.13 | 58 | 3, 4 |
| Cesium | Cs | 132.91 | 55 | 1 |
| Chlorine | Cl | 35.457 | 17 | 1, 3, 5, 7 |
| Chromium | Cr | 52.01 | 24 | 2, 3, 6 |
| Cobalt | Co | 58.94 | 27 | 2, 3 |
| Columbium (see Niobium) | -- | --- | -- | - - - |
| Copper | Cu | 63.54 | 29 | 1, 2 |

# PROPERTIES OF TYPICAL SOLID PROPELLANTS*

| Propellant Type | Composite | Composite | Composite | Composite | Composite | Double-Base | Double-Base | Double-Base | Double-Base |
|---|---|---|---|---|---|---|---|---|---|
| Method of Manufacture | Cast | Cast | Cast | Cast | Cast | Extruded | Cast | Cast | Cast |
| Oxidizer | Ammonium Perchlorate | Ammonium Nitrate | Ammonium Perchlorate | Ammonium and Potassium Perchlorate | Potassium Perchlorate | Nitrocellulose Nitroglycerin | Nitrocellulose Nitroglycerin | Ballistite | Cordite |
| Fuel | Polybutadiene-Acrylic Acid + Aluminum Powd. | Cellulose Acetate | Polyurethane | Polyurethane | Polyester-styrene | | | | |
| Chamber Pressure, Pc, psi Range | 15 to 2000 | 15 to 2000 | 15 to 2000 | 200 to 1800 | 400 to 2000 | 500 to 20,000 | 300-4200 | 1000-3000 | 1000-3000 |
| Characteristic Velocity, C*, fps | 5140 | 3500 | 4[illegible]10 | 4700 | 3600 | 4350 | 4450 | | |
| Theoretical Specific Impulse, Isp at Sea Level lb. sec./lb. $P_c$=1000psi | 250 | 17[illegible] | 238 | 236 | 178 | 216 (1) | 219 | 200 | 180 |
| Burning Rate, $r_o$ in./sec. at $P_c$=1000 psi | 0.467 | 0.086 | 0.227 | 0.479 | 0.69 | 0.46 | 0.45 | — | — |
| Exponent, n, in Burning Rate Equation $r_o = a_z P_c^n$ | 0.236 | 0.50 | 0.05 | — | 0.74 | 0.00 (2) | 0.61 (1) | 0.85 | 0.77 |
| Temperature Coefficient of Pressure, $\pi_x = \frac{1}{P_c}\left(\frac{\delta p}{\delta T}\right)_x$, (%/°F) | 0.115 | 0.26 | 0.13 | 0.22 | 0.33 | 0.09 | — | — | — |
| Density $\delta p$ lb./cu.in. | 0.063 | 0.056 | 0.062 | 0.063 | 0.068 | 0.056 | 0.057 | 0.043-0.061 | — |
| | | | | | | (1) at 1300 psi (2) Between 900-1200 psi | (1) Between 800-1650 psi | | |

* From: Principles of Guided Missile Design, Merrill, 1958

INTERNATIONAL ATOMIC WEIGHTS, 1959 (Continued)

| ELEMENTS | SYMBOL | ATOMIC WEIGHT | ATOMIC NUMBER | VALENCE |
|---|---|---|---|---|
| Curium | Cm | 247.0 | 96 | 3 |
| Dysprosium | Dy | 162.51 | 66 | 3 |
| Einsteinium | Es | 254.0 | 99 | - - - |
| Erbium | Er | 167.27 | 68 | 3 |
| Europium | Eu | 152.0 | 63 | 2, 3 |
| Fermium | Fm | 253.0 | 100 | - - - |
| Fluorine | F | 19.00 | 9 | 1 |
| Francium | Fr | 223.0 | 87 | 1 |
| Gadolinium | Gd | 157.26 | 64 | 3 |
| Gallium | Ga | 69.72 | 31 | 2, 3 |
| Germanium | Ge | 72.60 | 32 | 4 |
| Gold | Au | 197.0 | 79 | 1, 3 |
| Hafnium | Hf | 178.50 | 72 | 4 |
| Helium | He | 4.003 | 2 | 0 |
| Holmium | Ho | 164.94 | 67 | 3 |
| Hydrogen | H | 1.0080 | 1 | 1 |
| Indium | In | 114.82 | 49 | 3 |
| Iodine | I | 126.91 | 53 | 1, 3, 5, 7 |
| Iridium | Ir | 192.2 | 77 | 3, 4 |
| Iron | Fe | 55.85 | 26 | 2, 3 |
| Krypton | Kr | 83.80 | 36 | 0 |
| Lanthanum | La | 138.92 | 57 | 3 |
| Lead | Pb | 207.21 | 82 | 2, 4 |
| Lithium | Li | 6.940 | 3 | 1 |

INTERNATIONAL ATOMIC WEIGHTS, 1959 (Continued)

| ELEMENTS | SYMBOL | ATOMIC WEIGHT | ATOMIC NUMBER | VALENCE |
|---|---|---|---|---|
| Lutetium | Lu | 174.99 | 71 | 3 |
| Magnesium | Mg | 24.32 | 12 | 2 |
| Manganese | Mn | 54.94 | 25 | 2, 3, 4, 6, 7 |
| Mendelevium | Md | 256.0 | 101 | - - - |
| Mercury | Hg | 200.61 | 80 | 1, 2 |
| Molybdenum | Mo | 95.95 | 42 | 3, 4, 6 |
| Neodymium | Nd | 144.27 | 60 | 3 |
| Neon | Ne | 20.183 | 10 | 0 |
| Neptunium | Np | 237.0 | 93 | 4, 5, 6 |
| Nickel | Ni | 58.71 | 28 | 2, 3 |
| Niobium (Columbium) | Nb | 92.91 | 41 | 3, 5 |
| Nitrogen | N | 14.008 | 7 | 3, 5 |
| Osmium | Os | 190.2 | 76 | 2, 3, 4, 8 |
| Oxygen | O | 16.0000 | 8 | 2 |
| Palladium | Pd | 106.4 | 46 | 2, 4 |
| Phosphorus | P | 30.975 | 15 | 3, 5 |
| Platinum | Pt | 195.09 | 78 | 2, 4 |
| Plutonium | Pu | 242.0 | 94 | 3, 4, 5, 6 |
| Polonium | Po | 210.0 | 84 | - - - |
| Potassium | K | 39.100 | 19 | 1 |
| Praesodymium | Pr | 140.91 | 59 | 3 |
| Promethium | Pm | 147.0 | 61 | 3 |
| Protactinium | Pa | 231.0 | 91 | - - - |
| Radium | Ra | 226.0 | 88 | 2 |

INTERNATIONAL ATOMIC WEIGHTS, 1959 (Continued)

| ELEMENTS | SYMBOL | ATOMIC WEIGHT | ATOMIC NUMBER | VALENCE |
|---|---|---|---|---|
| Radon | Rn | 222.0 | 86 | 0 |
| Rhenium | Re | 186.22 | 75 | - - - |
| Rhodium | Rh | 102.91 | 45 | 3 |
| Rubidium | Rb | 85.48 | 37 | 1 |
| Ruthenium | Ru | 101.1 | 44 | 3, 4, 6, 8 |
| Samarium | Sm | 150.35 | 62 | 2, 3 |
| Scandium | Sc | 45.96 | 21 | 3 |
| Selenium | Se | 78.96 | 34 | 2, 4, 6 |
| Silicon | Si | 28.09 | 14 | 4 |
| Silver | Ag | 107.880 | 47 | 1 |
| Sodium | Na | 22.991 | 11 | 1 |
| Strontium | Sr | 87.63 | 38 | 2 |
| Sulfur | S | 32.066 | 16 | 2, 4, 6 |
| Tantalum | Ta | 180.95 | 73 | 5 |
| Technetium | Tc | 99.0 | 43 | 6, 7 |
| Tellurium | Te | 127.61 | 52 | 2, 4, 6 |
| Terbium | Tb | 158.93 | 65 | 3 |
| Thallium | Tl | 204.39 | 81 | 1, 3 |
| Thorium | Th | 232.0 | 90 | 4 |
| Thulium | Tm | 168.94 | 69 | 3 |
| Tin | Sn | 118.70 | 50 | 2, 4 |
| Titanium | Ti | 47.90 | 22 | 3, 4 |
| Tungsten (see Wolfram) | -- | --- | -- | - - - |

INTERNATIONAL ATOMIC WEIGHTS, 1959 (Continued)

| ELEMENTS | SYMBOL | ATOMIC WEIGHT | ATOMIC NUMBER | VALENCE |
|---|---|---|---|---|
| Uranium | U | 238.0 | 92 | 4, 6 |
| Vanadium | V | 50.95 | 23 | 3, 5 |
| Wolfram (Tungsten) | W | 183.86 | 74 | 6 |
| Xenon | Xe | 131.30 | 54 | 0 |
| Ytterbium | Yb | 173.04 | 70 | 2, 3 |
| Yttrium | Y | 88.91 | 39 | 3 |
| Zinc | Zn | 65.38 | 30 | 2 |
| Zirconium | Zr | 91.22 | 40 | 4 |

* Taken from Periodic Chart of The Atoms

By Hubbard and Meggers

Revised Edition 1959

# CONVERSION FACTORS

| LENGTH | MULTIPLY BY | TO OBTAIN |
|---|---|---|
| Centimeters | 0.3937 | Inches |
| | 0.03281 | Feet |
| Kilometers | 3281 | Feet |
| | 0.6214 | Miles |
| | 0.5396 | Nautical Miles |
| | 1093.6 | Yards |
| Meters | 39.37 | Inches |
| | 3.281 | Feet |
| | 1.0936 | Yards |
| Miles | 5280 | Feet |
| | 0.8684 | Nautical Miles |
| | 1760 | Yards |
| Nautical Miles | 6080.2 | Feet |
| **WEIGHT** | | |
| Grams | 15.432 | Grains |
| | 0.03527 | Ounces (avdp.) |
| | 0.002205 | Pounds (avdp.) |
| | 1000 | Milligrams |
| | 0.001 | Kilograms |
| Kilograms | 2.205 | Pounds (avdp.) |
| | 35.27 | Ounces (avdp.) |
| | 1000 | Grams |
| Pounds (avdp.) | 7000 | Grains |
| | 16.0 | Ounces |
| | 1.215 | Pounds (Troy) |
| Tons (Long) | 2240 | Pounds (avdp.) |
| Tons (Metric) | 1000 | Kilograms |
| | 2205 | Pounds (avdp.) |
| | 1.102 | Tons (Short) |
| **VOLUME** | | |
| Barrels | 42 | Gallons (Oil) |
| Cubic Centimeters | $10^{-3}$ | Liters |
| | 0.0610 | Cubic Inches |

CONVERSION FACTORS (Continued)

| VOLUME | MULTIPLY BY | TO OBTAIN |
|---|---|---|
| Cubic Feet | 28317 | Cubic Centimeters |
| | 1728 | Cubic Inches |
| | 0.03704 | Cubic Yards |
| | 7.481 | Gallons |
| | 28.32 | Liters |
| Cubic Inches | $4.329 \times 10^{-3}$ | Gallons |
| | 0.01732 | Quarts (Liquid) |
| Cubic Meters | 61023 | Cubic Inches |
| | 35.31 | Cubic Feet |
| | 264.17 | Gallons |
| | 1.308 | Cubic Yards |
| Gallons, Imperial | 277.4 | Cubic Inches |
| | 1.201 | U.S. Gallons, Liquid |
| | 4.546 | Liters |
| Gallons, U.S. Dry | 268.8 | Cubic Inches |
| | 0.1556 | Cubic Feet |
| | 1.164 | Gals. U.S. Liquid |
| | 4.404 | Liters |
| Gallons, U.S. Liquid | 231 | Cubic Inches |
| | 0.1337 | Cubic Feet |
| | 3.785 | Liters |
| | 128 | Liquid Ounces |
| Ounces Fluid | 29.57 | Cubic Centimeters |
| | 1.805 | Cubic Inches |

| AREA | | |
|---|---|---|
| Acres | 43560 | Square Feet |
| | 4047 | Square Meters |
| | $1.562 \times 10^{-3}$ | Square Miles |
| Circular Mils | $7.854 \times 10^{-7}$ | Square Inches |
| | $5.067 \times 10^{-4}$ | Square Millimeters |
| | 0.7854 | Square Mils |
| Square Centimeters | 0.1550 | Square Inches |
| | 0.001076 | Square Feet |
| Square Inches | 645.16 | Square Millimeters |
| Square Kilometers | 0.3861 | Square Miles |

CONVERSION FACTORS (Continued)

| AREA | MULTIPLY BY | TO OBTAIN |
|---|---|---|
| Square Meters | 10.76 | Square Feet |
| | 1.196 | Square Yards |
| Square Miles | 2.590 | Square Kilometers |
| | 640 | Acres |
| **VELOCITY** | | |
| Feet Per Minute | 0.01136 | Miles Per Hour |
| | 0.01829 | Kilometers Per Hour |
| | 0.5080 | Centimeters Per Sec. |
| | 0.01667 | Feet Per Second |
| Feet Per Second | 0.6818 | Miles Per Hour |
| | 1.097 | Kilometers Per Hour |
| | 30.48 | Centimeters Per Sec. |
| | 0.3048 | Meters Per Second |
| | 0.5921 | Knots |
| Knots | 1.0 | Nautical Miles Per Hour |
| | 1.6889 | Feet Per Second |
| | 1.1515 | Miles Per Hour |
| | 0.5148 | Meters Per Second |
| Miles Per Hour | 1.467 | Feet Per Second |
| | 0.4470 | Meters Per Second |
| | 1.609 | Kilometers Per Hour |
| | 0.8684 | Knots |
| Radians Per Second | 57.296 | Degrees Per Second |
| | 0.1592 | Revolutions Per Sec. |
| | 9.55 | Revolutions Per Min. |
| **PRESSURE** | | |
| Atmospheres | 76.0 | Centimeters of Mercury |
| | 29.921 | Inches of Mercury |
| | 33.93 | Feet of Water |
| | 10332 | Kilograms Per Sq. Meter |
| | 2116.2 | Lbs. Per Square Foot |
| **VISCOSITY** | | |
| (Kinematic Viscosity) | Density | (Absolute Viscosity) |

CONVERSION FACTORS (Continued)

| VOLUME | MULTIPLY BY | TO OBTAIN |
|---|---|---|
| Cubic Feet | 28317 | Cubic Centimeters |
| | 1728 | Cubic Inches |
| | 0.03704 | Cubic Yards |
| | 7.481 | Gallons |
| | 28.32 | Liters |
| Cubic Inches | $4.329 \times 10^{-3}$ | Gallons |
| | 0.01732 | Quarts (Liquid) |
| Cubic Meters | 61023 | Cubic Inches |
| | 35.31 | Cubic Feet |
| | 264.17 | Gallons |
| | 1.308 | Cubic Yards |
| Gallons, Imperial | 277.4 | Cubic Inches |
| | 1.201 | U.S. Gallons, Liquid |
| | 4.546 | Liters |
| Gallons, U.S. Dry | 268.8 | Cubic Inches |
| | 0.1556 | Cubic Feet |
| | 1.164 | Gals. U.S. Liquid |
| | 4.404 | Liters |
| Gallons, U.S. Liquid | 231 | Cubic Inches |
| | 0.1337 | Cubic Feet |
| | 3.785 | Liters |
| | 128 | Liquid Ounces |
| Ounces Fluid | 29.57 | Cubic Centimeters |
| | 1.805 | Cubic Inches |

| AREA | | |
|---|---|---|
| Acres | 43560 | Square Feet |
| | 4047 | Square Meters |
| | $1.562 \times 10^{-3}$ | Square Miles |
| Circular Mils | $7.854 \times 10^{-7}$ | Square Inches |
| | $5.067 \times 10^{-4}$ | Square Millimeters |
| | 0.7854 | Square Mils |
| Square Centimeters | 0.1550 | Square Inches |
| | 0.001076 | Square Feet |
| Square Inches | 645.16 | Square Millimeters |
| Square Kilometers | 0.3861 | Square Miles |

## CONVERSION FACTORS (Continued)

| AREA | MULTIPLY BY | TO OBTAIN |
|---|---|---|
| Square Meters | 10.76 | Square Feet |
| | 1.196 | Square Yards |
| Square Miles | 2.590 | Square Kilometers |
| | 640 | Acres |
| **VELOCITY** | | |
| Feet Per Minute | 0.01136 | Miles Per Hour |
| | 0.01829 | Kilometers Per Hour |
| | 0.5080 | Centimeters Per Sec. |
| | 0.01667 | Feet Per Second |
| Feet Per Second | 0.6818 | Miles Per Hour |
| | 1.097 | Kilometers Per Hour |
| | 30.48 | Centimeters Per Sec. |
| | 0.3048 | Meters Per Second |
| | 0.5921 | Knots |
| Knots | 1.0 | Nautical Miles Per Hour |
| | 1.6889 | Feet Per Second |
| | 1.1515 | Miles Per Hour |
| | 0.5148 | Meters Per Second |
| Miles Per Hour | 1.467 | Feet Per Second |
| | 0.4470 | Meters Per Second |
| | 1.609 | Kilometers Per Hour |
| | 0.8684 | Knots |
| Radians Per Second | 57.296 | Degrees Per Second |
| | 0.1592 | Revolutions Per Sec. |
| | 9.55 | Revolutions Per Min. |
| **PRESSURE** | | |
| Atmospheres | 76.0 | Centimeters of Mercury |
| | 29.921 | Inches of Mercury |
| | 33.93 | Feet of Water |
| | 10332 | Kilograms Per Sq. Meter |
| | 2116.2 | Lbs. Per Square Foot |
| **VISCOSITY** | | |
| (Kinematic Viscosity) | Density | (Absolute Viscosity) |

CONVERSION FACTORS (Continued)

| POWER | MULTIPLY BY | TO OBTAIN |
|---|---|---|
| BTU Per Minute | 12.96 | Foot-Lbs. Per Sec. |
| | 0.02356 | Horsepower |
| | 17.57 | Watts |
| | 0.2520 | Kilogram-Calories Per Minute |
| **HORSEPOWER** | 33000 | Foot-Lbs. Per Min. |
| | 550 | Foot-Lbs. Per Sec. |
| | 76.040 | Kilogram-Meters Per Second |
| | 1.014 | Metric Horsepower |
| | 42.41 | BTU Per Minute |
| | 10.68 | Kilogram-Calories Per Minute |
| | 0.7457 | Kilowatts |
| **ENERGY** | | |
| BTU | 778.2 | Foot-Pounds |
| | 1055 | Joules |
| **TEMPERATURE** | | |
| Fahrenheit | 5/9 (F-32) | Centigrade |
| Centigrade | 9/5 (C + 17.8) | Fahrenheit |

REFERENCE: Pocket Data for Rocket Engines, by Bell Aircraft Corp., Buffalo 5, N. Y.

## TEMPERATURE CONVERSION TABLE

| -459.4 to -200 | | -190 to +8 | | 9 to 36 | | 37 to 64 | | 65 to 92 | | 93 to 280 | | 290 to 560 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C. | F. | C. | F. | C. | F. | C. | F. | C. | F. | C. | F. | C. | F. |
| -273 | -459.4 | -123 | -190 | -12.7 | 9 | 2.7 | 37 | 18.2 | 65 | 33.8 | 93 | 143 | 290 |
| -268 | -450 | -118 | -180 | -12.2 | 10 | 3.3 | 38 | 18.8 | 66 | 34.4 | 94 | 149 | 300 |
| -262 | -440 | -112 | -170 | -11.6 | 11 | 3.8 | 39 | 19.3 | 67 | 34.9 | 95 | 154 | 310 |
| -257 | -430 | -107 | -160 | -11.1 | 12 | 4.4 | 40 | 19.9 | 68 | 35.5 | 96 | 160 | 320 |
| -251 | -420 | -101 | -150 | -10.5 | 13 | 4.9 | 41 | 20.4 | 69 | 36.1 | 97 | 165 | 330 |
| -246 | -410 | - 96 | -140 | -10.0 | 14 | 5.5 | 42 | 21.0 | 70 | 36.6 | 98 | 171 | 340 |
| -240 | -400 | - 90 | -130 | - 9.4 | 15 | 6.0 | 43 | 21.5 | 71 | 37.1 | 99 | 177 | 350 |
| -234 | -390 | - 84 | -120 | - 8.8 | 16 | 6.6 | 44 | 22.2 | 72 | 37.7 | 100 | 182 | 360 |
| -229 | -380 | - 79 | -110 | - 8.3 | 17 | 7.1 | 45 | 22.7 | 73 | 38 | 100 | 188 | 370 |
| -223 | -370 | - 73 | -100 | - 7.7 | 18 | 7.7 | 46 | 23.3 | 74 | 43 | 110 | 193 | 380 |
| -218 | -360 | - 68 | - 90 | - 7.2 | 19 | 8.2 | 47 | 23.8 | 75 | 49 | 120 | 199 | 390 |
| -212 | -350 | - 62 | - 80 | - 6.6 | 20 | 8.8 | 48 | 24.4 | 76 | 54 | 130 | 204 | 400 |
| -207 | -340 | - 57 | - 70 | - 6.1 | 21 | 9.3 | 49 | 25.0 | 77 | 60 | 140 | 210 | 410 |
| -201 | -330 | - 51 | - 60 | - 5.5 | 22 | 9.9 | 50 | 25.5 | 78 | 65 | 150 | 215 | 420 |
| -196 | -320 | - 46 | - 50 | - 5.0 | 23 | 10.4 | 51 | 26.2 | 79 | 71 | 160 | 221 | 430 |
| -190 | -310 | - 40 | - 40 | - 4.4 | 24 | 11.1 | 52 | 26.8 | 80 | 76 | 170 | 226 | 440 |
| -184 | -300 | - 34 | - 30 | - 3.9 | 25 | 11.5 | 53 | 27.3 | 81 | 83 | 180 | 232 | 450 |
| -179 | -290 | - 29 | - 20 | - 3.3 | 26 | 12.1 | 54 | 27.7 | 82 | 88 | 190 | 238 | 460 |
| -173 | -280 | - 23 | - 10 | - 2.8 | 27 | 12.6 | 55 | 28.2 | 83 | 93 | 200 | 243 | 470 |
| -169 | -273 | -17.7 | 0 | - 2.2 | 28 | 13.2 | 56 | 28.8 | 84 | 99 | 210 | 249 | 480 |
| -168 | -270 | -17.2 | 1 | - 1.6 | 29 | 13.7 | 57 | 29.3 | 85 | 100 | 212 | 254 | 490 |
| -162 | -260 | -16.6 | 2 | - 1.1 | 30 | 14.3 | 58 | 29.9 | 86 | 104 | 220 | 260 | 500 |
| -157 | -250 | -16.1 | 3 | - 0.6 | 31 | 14.8 | 59 | 30.4 | 87 | 110 | 230 | 265 | 510 |
| -151 | -240 | -15.5 | 4 | 0 | 32 | 15.6 | 60 | 31.0 | 88 | 115 | 240 | 271 | 520 |
| -146 | -230 | -15.0 | 5 | 0.5 | 33 | 16.1 | 61 | 31.5 | 89 | 121 | 250 | 276 | 530 |
| -140 | -220 | -14.4 | 6 | 1.1 | 34 | 16.6 | 62 | 32.1 | 90 | 127 | 260 | 282 | 540 |
| -134 | -210 | -13.9 | 7 | 1.6 | 35 | 17.1 | 63 | 32.6 | 91 | 132 | 270 | 288 | 550 |
| -129 | -200 | -13.3 | 8 | 2.2 | 36 | 17.7 | 64 | 33.3 | 92 | 138 | 280 | 293 | 560 |

| WEIGHT OF MATERIALS | | | | | |
|---|---|---|---|---|---|
| MATERIAL | SPECIFIC GRAVITY | DENSITY 1B/IN.$^3$ | MATERIAL | SPECIFIC GRAVITY | DENSITY 1B/IN.$^3$ |
| ALUMINUM | 2.70 | 0.097 | IRON, WROUGHT | 7.90 | 0.284 |
| AL ALLOYS, 2S | 2.71 | 0.098 | KEL-F | 2.1 | 0.076 |
| 3S | 2.73 | 0.099 | K-MONEL | 8.58 | 0.310 |
| 4S | 2.72 | 0.098 | LEAD | 11.40 | 0.411 |
| 24S | 2.79 | 0.101 | LEATHER | 0.95 | 0.034 |
| 52S | 2.66 | 0.096 | MAGNESIUM | 1.74 | 0.063 |
| 195 | 2.77 | 0.100 | MAGNESIUM ALLOYS | 1.80 | 0.065 |
| 355 | 2.68 | 0.097 | MICARTA | 1.35 | 0.049 |
| ASBESTOS | 2.46 | 0.089 | MONEL | 8.90 | 0.323 |
| BAKELITE | 1.35 | 0.049 | NICKEL | 8.90 | 0.324 |
| BERYLLIUM | 1.8 | 0.065 | NYLON | 1.08 TO 1.15 | 0.039 TO 0.0416 |
| BRASS | 8.45 TO 8.70 | 0.305 TO 0.313 | PLASTECELE | 1.35 | 0.049 |
| BRONZE, AL | 7.70 | 0.278 | PLEXIGLAS | 1.18 | 0.043 |
| BRONZE, PHOS | 8.89 | 0.321 | POLYETHYLENE | 0.92 | 0.033 |
| COPPER | 8.90 | 0.322 | PYRALIN | 1.35 | 0.049 |
| CORK, COMPRESSED | 0.23 | 0.008 | RUBBER (ENG. MOUNT.) | | |
| FELT | 0.08 | 0.003 | 45 DUROMETER READING | 1.06 | 0.038 |
| FORMICA | 1.35 | 0.048 | 50 DUROMETER READING | 1.11 | 0.040 |
| GLASS, SAFETY | 2.53 | 0.091 | 60 DUROMETER READING | 1.17 | 0.042 |
| GOLD | 19.32 | 0.697 | 70 DUROMETER READING | 1.24 | 0.044 |
| INCONEL | 8.55 | 0.309 | SILVER | 10.50 | 0.380 |
| IRON, CAST | 7.20 | 0.26[illegible] | STEEL | 7.84 | 0.283 |

## WEIGHT OF MATERIALS

| MATERIAL | SPECIFIC GRAVITY | DENSITY 1B/IN.$^3$ | MATERIAL | SPECIFIC GRAVITY | DENSITY 1B/IN.$^3$ |
|---|---|---|---|---|---|
| STEEL, STAINLESS | 7.86 | 0.284 | WOODS, FIR | 0.48 TO 0.55 | 0.017 TO 0.020 |
| TEFLON | 2.1 TO 2.3 | 0.076 TO 0.83 | HICKORY | 0.74 TO 0.80 | 0.027 TO 0.029 |
| TITANIUM | 4.5 | 0.162 | MAHOGANY | 0.56 TO 0.85 | 0.02[illegible] TO 0.031 |
| TIN | 7.29 | 0.263 | PINE | 0.38 TO 0.60 | 0.014 TO 0.022 |
| VINYLITE | 1.4 | 0.0506 | SPRUCE | 0.48 TO 0.70 | 0.017 TO 0.025 |
| WOODS, ASH | 0.66 TO 0.85 | 0.024 TO 0.031 | BALSA | 0.12 TO 0.20 | 0.00435 TO 0.00724 |
| CEDAR | 0.44 TO 0.57 | 0.018 TO 0.021 | ZINC | 7.19 | 0.258 |

## SOLID PROPELLANT JATO NOMENCLATURE
(JATO - Jet Assisted Take-Off)

A JATO unit is defined as an auxiliary rocket that can be attached to a vehicle for the purpose of applying thrust when needed. It is further defined as a complete, self-contained rocket unit that has a definite burning time and a fixed thrust. The word JATO has been adopted as the basic term for jet thrust units and includes boosters, sustainers and aircraft assist take-off devices.

The complete JATO nomenclature consists of the following three (3) parts:

1. Basic Name

   The basic name is Jet Assisted Take-Off and is abbreviated JATO.

2. Description

   The description is composed of the following:

   a. Numerals denoting thrust duration in seconds (at 70°F)

   b. Two (2) letter symbols denoting the type and physical state of the propellant. This two letter symbol must be followed by a dash (-)

   The letter symbols for the type of propellant are as follows:

| SYMBOL | TYPE |
|---|---|
| A | Acid with fuel or asphalt with perchlorate |
| B | Ball or chopped double-base |
| C | Composite (picrate-nitrate) |
| D | Cast double-base |
| E | Extruded double-base |
| F | Furfuryl alcohol with oxidizer (includes all alcohols higher than ethyl) |
| H | Hydride fuels |
| K | Cast perchlorates (binder fuels other than asphalt) |

| SYMBOL | TYPE |
|---|---|
| N | Nitrates and nitro-compounds (other than those designated above) |
| O | Liquid oxygen with alcohol or other hydrocarbons |

| SYMBOL | PHYSICAL STATE |
|---|---|
| L | Liquids |
| P | Plastic compositions |
| S | Solids |

c. Numerals denoting the approximate thrust in pounds produced by the unit (at 70°F).

3. Identification

The identification consists of various symbols and numerals used to define the status, model and design sequence of the JATO unit.

Minor variations exist in the identifications used by the Air Force, Army and Navy.

a. Air Force and Army JATOS

The Air Force and Army service standard JATO units are designated with the letter M and subsequent standard modifications are designated with the letter A. Frequently standard units are experimentally modified and designated by M E. Experimental units are designated with a T and subsequent experimental modifications are designated with the letter E.

b. Navy JATOS

Navy service standard JATO units are designated according to purpose and by the letters Mk. Subsequent standard modifications are designated by Mod. Experimental units are designated with an X followed by a three (3) digit number. The three (3) digit numbers are the 100 series reserved for JATOS manufactured by the Aerojet-General Corp.; 200 series for the Allegany Ballistics; and 300 series for NOTS (Naval Ordnance Test Station). Major modifications of JATO units are designated by a letter of the alphabet and subsequent minor modifications are designated by a number.

Examples

1. 2.3 DS-62000 JATO Unit M3E1

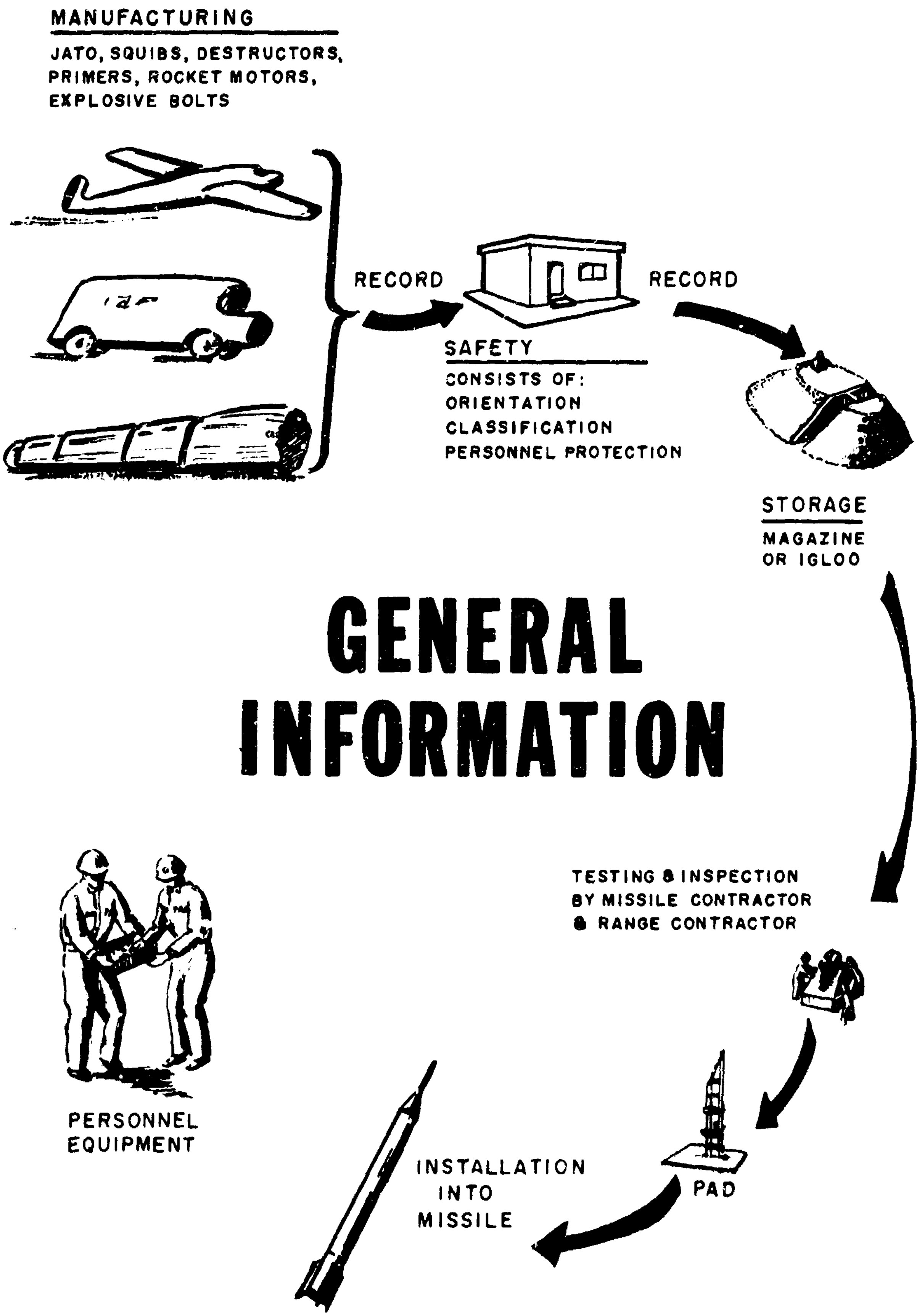
   This is the complete nomenclature for an Air Force or Army JATO unit.

   The JATO unit would be a 2.3 second thrust duration (at 70°F), cast double-base (D), solid propellants (S) unit of 62,000 pounds thrust. Its identification M3E1 means that it is an Air Force or Army JATO experimental standard service unit (designated by M3) and the experimental unit modified one time (E1).

2. 18 KS-50000 Missile Booster Mk6 Mod 1

   This is the complete nomenclature for a Navy service standard JATO (Mk6), missile booster, having one (1) modification (Mod 1). The cast perchlorate (K), solid propellant (S) would have a thrust duration of eighteen (18) seconds and a thrust of 50,000 pounds.

# GENERAL INFORMATION




PAN AMERICAN WORLD AIRWAYS
GUIDED MISSILES RANGE DIVISION
PATRICK AIR FORCE BASE, FLORIDA

REVISION SHEET

1. Basic Communication February 1960

# GENERAL INFORMATION

## I. CLASSIFICATION OF MILITARY EXPLOSIVES AND AMMUNITION

Explosives and ammunition may be classified according to the following characteristics:

A. Type

1. Small-Arms Ammunition

Small-arms ammunition consists of cartridges used in rifles, carbines, revolvers, pistols, submachine guns, machine guns and shells used in shotguns.

2. Grenades

Grenades are explosive or chemical-filled projectiles. They are designed to be thrown by hand or projected from a rifle.

3. Artillery and Cannon Powder Ammunition

Artillery and cannon powder ammunition consists of cartridges, shot and shells that are filled with high explosives, chemicals or other active agents and projectiles that are used in guns, howitzers, mortars and recoilless rifles.

4. Bombs

Bombs are containers filled with explosives, chemicals or other active agents designed for release from aircraft.

5. Pyrotechnics

Pyrotechnics consist of containers filled with low explosive compositions. They are designed to be released from aircraft or projected from the ground. They are used for illumination, signals and photoflash bombs.

6. Rockets

Rockets are propellant-type motors fitted with rocket heads containing high explosives or chemical agents. Rocket motors in the research and development phase do not include an explosive warhead.

7. JATOS

JATOS are auxiliary rockets that can be attached to a vehicle for the purpose of applying thrust when needed. They are further described as complete, self-contained rocket units that have a definite burning time and a fixed thrust. The word JATO has been adopted as the basic term for jet thrust units and includes boosters, sustainers and aircraft assist take-off devices.

8. Land Mines

Land mines are containers, metal or plastic, that contain high explosive or chemical agents. They are designed to be laid in or on the ground and are initiated by, and directed against, enemy vehicles or personnel.

9. Guided Missiles

Tactical guided missiles consist of propellant-type motors fitted with warheads containing high explosives or other active agents and equipped with electronic guidance devices. Guided missiles in various stages of research and development do not contain explosive warheads but use high explosives in ignition and safety-destruct units only.

10. Demolition Materials

Demolition materials consist of explosives and explosive devices designed for use in demolition and for blasting in military construction.

11. Cartridge-Actuated Devices

Cartridge-actuated devices are devices designed to facilitate the emergency escape of personnel from high-speed aircraft.

B. Chemical Composition

1. Inorganic Compounds

Examples of inorganic compounds are:

a. Lead azide

b. Ammonium nitrate.

2. Organic Compounds

Examples of organic compounds are:

a. Nitric esters, e.g. nitroglycerin and nitrocellulose

b. Nitro-compounds, e.g. TNT and picric acid

c. Nitramines, e.g. haleite

d. Nitroso-compounds, e.g. tetracene

e. Metallic derivatives, e.g. mercury fulminate and lead styphnate.

3. Mixtures of Fuels and Oxidizers

Mixtures of fuels and oxidizers are non-explosives when used separately but become explosives when combined. Black powder and pyrotechnic compositions are examples of this class.

C. Function

1. Low Explosives That Undergo Auto-Combustion

Examples of this class are black powder, pyrotechnic compositions and colloided nitrocellulose.

2. High Explosives That Undergo Detonation

Examples of this class are as follows:

a. Initiating agents that can be detonated by spark, friction or impact and can initiate the detonation of relatively insensitive explosives. Examples are lead azide and mercury fulminate.

b. Non-initiating explosives that must be detonated by an initiating agent. These are described as follows:

(1) Booster explosives

Examples of booster explosives are tetryl and PETN which are easily initiated and detonate at high rates. These explosives are not suitable for loading in mass charges.

(2) Bursting charge explosives

Examples of this group include TNT and Explosive D. These explosives are usually initiated by means of a booster explosive. They can be loaded in mass charges.

(3) Explosives that are either too sensitive or too insensitive to be used alone. These explosives can only be used as ingredients of mixtures. An example of the too sensitive type is nitroglycerin. An example of the too insensitive type is ammonium nitrate.

By utilizing the special characteristics of the explosives in these classes, it is practical to establish the "explosive train." An example of an explosive train is the initiation of a priming composition by electrical or mechanical means which, in turn, detonates a charge of lead azide. This initiates the detonation of a booster charge of tetryl which, in turn, effects the detonation of a surrounding bursting charge of TNT.

D. Storage

Explosives and ammunition are classified for storage purposes into quantity-distance classes 1 to 12 inclusive (see "Air Force and Army Quantity-Distance Classification of Explosives and Ammunition," pages 1-6 thru 1-25 and Table 1-1, "General Classification of Explosives and Ammunition with Fire Symbols Included," pages 1-26 thru 1-32).

E. Storage Compatibility

Explosives and ammunition are classified for storage into seventeen (17) groups which are lettered A thru Q (see "Air Force and Army Group Summary of Storage Compatibility for Explosives and Ammunition," pages 1-33 thru 1-40). These groups should not be confused with the hazard classification established for quantity-distance requirements. Where two (2) or more quantity-distance classes of explosives and ammunition are stored together in a magazine, the quantity-distance requirements will apply for the most hazardous material stored therein.

F. Interstate Commerce Commission Shipping Regulations

Explosives and ammunition are classified by Freight Tariff No. 9, which publishes ICC shipping regulations, into Class A, Class B and Class C explosives (see Table 1-2, "Loading and Storage Chart of Explosives and Other Dangerous Articles," pages 1-41 thru 1-43).

G. Burning or Explosive Characteristics

Explosives and ammunition are classified into four (4) groups according to their general burning or explosive characteristics. These groups are identified

by "symbols," which are the Arabic numerals 1, 2, 3 and 4. Each group consists of one or more specific quantity-distance classes (see pages 1-83 thru 1-86, "Description of Fire-Hazard Symbols" in the subsection entitled "Storage of Explosives and Ammunition").

H. Security

In accordance with Security Regulations explosives and ammunition are classified as follows:

1. Unclassified

2. Confidential

3. Secret

4. Top Secret.

AIR FORCE AND ARMY QUANTITY-DISTANCE

CLASSIFICATION OF

EXPLOSIVES AND AMMUNITION

(Classes 1 through 12 applicable
Quantity-Distance Tables)

## AIR FORCE AND ARMY QUANTITY-DISTANCE CLASSIFICATION OF EXPLOSIVES AND AMMUNITION

### Class 1 Quantity-Distance Items

The items in this class are primarily fire hazards and no quantity-distances are assessed for storage. The following items are included in class 1:

1. Aluminum powder (packed and stored in original shipping containers or equivalent).
2. Ammunition, caliber 20-mm or less, except HE, HE-I and 20-mm incendiary rounds.
3. Cartridge-actuated devices.
4. Charge, spotting, A. P., practice, M8.
5. Chlorates (packed and stored in original shipping containers or equivalent).
6. Corporal, actuator, assembly propellant valve, quick release.
7. Cutter, reefing line.
8. Firing devices.
9. Fuse lighters.
10. Fuse, safety.
11. Ignition cartridges for mortar ammunition.
12. Magnesium powder (packed and stored in original shipping containers or equivalent).
13. Nitrates (inorganic, packed and stored in original shipping containers or equivalent).
14. Perchlorates (packed and stored in original shipping containers or equivalent).
15. Peroxides (except high strength hydrogen peroxide), packed and stored in original shipping containers or equivalent.
16. Squibs, commercial.

17. Thermite.

18. Zirconium (size of particles 20 mesh, U. S. standard sieve, or greater) packed and stored in original shipping containers or equivalent.

## Class 2 Quantity-Distance Items

These materials may become unsafe under extreme conditions of moisture, high temperature or age. They burn with intense heat but usually do not form dangerous projectiles or generate pressures which will cause serious structural damage to adjacent magazines. Table 1 shows quantity-distance relationships of class 2 items, which consist of the following:

1. Chemical ammunition, groups C and D when not assembled with explosive components.

2. Ball, cellulose, nitrate, powder-filled.

3. Grenade, illuminating.

4. Military pyrotechnics (exclusive of classes 4 and 9 items).

   a. Flares.

   b. Illuminants.

   c. Incendiary ammunition including projectiles, bombs, grenades and exclusive of HE-I rounds.

   d. Igniters and tracer units (for ammunition).

   e. Signals including signal lights, smoke signals and obscuring smoke.

   NOTE: When the items listed in "a" through "e" above are packed and ready for shipment, they may be stored at one-half (1/2) the applicable class 2 quantity-distance requirements.

5. Projectiles, illuminating, when not assembled with explosive components.

6. Propellant, solid. Single-base, multiperforated, having a web thickness greater than 0.019 inch.

7. Pyrotechnic materials (exclusive of classes 9 and 10 items) and when not packed or stored in original shipping containers or equivalent, such as:

   a. Powdered metals.

   b. Chlorates.

   c. Perchlorates.

   d. Peroxides.

   e. Illuminating, flare or signal compositions which have been consolidated in the final press operations.

      NOTE: These compositions may be stored at one-half (1/2) the applicable class 2 quantity-distance.

   f. Thermate and other similar incendiary compositions.

8. Rocket heads WP loaded, when not assembled with explosive components.

9. Spotting charges (cartridges for miniature practice bombs).

10. Bomb, photoflash, M122, W/O burster (this item with burster is in class 10).

TABLE I - CLASS 2 QUANTITY-DISTANCE

| Quantity (lb) | | Minimum distance in feet from nearest | | | |
|---|---|---|---|---|---|
| Over | Not Over | Inhabited Building | Public Railway | Public Highway | Magazine and Intraline |
| Items In Approved Storage Containers And/Or Cartridge Cases | | | | | |
| 100 | 1,000 | 75 | 75 | 75 | 50 |
| 1,000 | 5,000 | 115 | 115 | 115 | 75 |
| 5,000 | 10,000 | 150 | 150 | 150 | 100 |
| 10,000 | 20,000 | 190 | 190 | 190 | 125 |
| 20,000 | 30,000 | 215 | 215 | 215 | 145 |
| 30,000 | 40,000 | 235 | 235 | 235 | 155 |
| 40,000 | 50,000 | 250 | 250 | 250 | 165 |
| 50,000 | 60,000 | 260 | 260 | 260 | 175 |
| 60,000 | 70,000 | 270 | 270 | 270 | 185 |
| 70,000 | 80,000 | 280 | 280 | 280 | 190 |
| 80,000 | 90,000 | 295 | 295 | 295 | 195 |
| 90,000 | 100,000 | 300 | 300 | 300 | 200 |
| 100,000 | 200,000 | 375 | 375 | 375 | 250 |
| 200,000 | 300,000 | 450 | 450 | 450 | 300 |
| 300,000 | 400,000 | 525 | 525 | 525 | 350 |
| 400,000 | 500,000* | 600 | 600 | 600 | 400 |
| Solid Propellant in Bulk (not in containers) | | | | | |
| 100 | 1,000 | 100 | 100 | 100 | 50 |
| 1,000 | 5,000 | 150 | 150 | 150 | 75 |
| 5,000 | 10,000 | 200 | 200 | 200 | 100 |
| 10,000 | 20,000 | 250 | 250 | 250 | 125 |
| 20,000 | 30,000 | 285 | 285 | 285 | 145 |
| 30,000 | 40,000 | 310 | 310 | 310 | 155 |
| 40,000 | 50,000 | 330 | 330 | 330 | 165 |
| 50,000 | 60,000 | 345 | 345 | 345 | 175 |
| 60,000 | 70,000 | 360 | 360 | 360 | 185 |
| 70,000 | 80,000 | 375 | 375 | 375 | 190 |
| 80,000 | 90,000 | 390 | 390 | 390 | 195 |
| 90,000 | 100,000 | 400 | 400 | 400 | 200 |
| 100,000 | 200,000 | 500 | 500 | 500 | 250 |
| 200,000 | 300,000* | 600 | 600 | 600 | 300 |

* Maximum quantity permitted at any one location.

## Class 2A Quantity-Distance Items

These materials are similar to class 2 except that they are potential explosion hazards whereas class 2 items are only potential fire hazards under ordinary conditions. The propellants listed are considered class 2A when stored in metal-lined wooden boxes; class 9 when stored in all-metal boxes. Table II shows quantity-distance relationships of class 2A items, which consist of the following:

1. Any double-base propellants containing not more than twenty (20) per cent nitroglycerin and having a web thickness of 0.0075 inch or greater.

2. Multiperforated cannon and rifle propellant having a web thickness of not greater than 0.019 inch.

3. Single-base (FNH and NH compositions), single perforated cannon propellant, having a web thickness not greater than 0.035 inch.

4. Single-base, single perforated rifle propellant.

5. Single-base pistol, shotgun and similar low pressure propellants.

6. M15 and M17 nitroguanadine propellants.

TABLE II - CLASS 2A QUANTITY-DISTANCE

| Quantity of explosive | | Unbarricaded distance in feet from nearest | | | |
|---|---|---|---|---|---|
| Pounds (over) | Pounds (not over) | Inhabited Building | Public Highway | Public Railway | Magazine (intraline distance) |
| 50 | 250 | 50 | 50 | 50 | 35 |
| 250 | 500 | 75 | 75 | 75 | 50 |
| 500 | 2,500 | 115 | 115 | 115 | 75 |
| 2,500 | 5,000 | 150 | 150 | 150 | 100 |
| 5,000 | 10,000 | 190 | 190 | 190 | 125 |
| 10,000 | 15,000 | 215 | 215 | 215 | 145 |
| 15,000 | 20,000 | 235 | 235 | 235 | 155 |
| 20,000 | 25,000 | 250 | 250 | 250 | 165 |
| 25,000 | 30,000 | 260 | 260 | 260 | 175 |
| 30,000 | 35,000 | 270 | 270 | 270 | 185 |
| 35,000 | 40,000 | 280 | 280 | 280 | 190 |
| 40,000 | 45,000 | 295 | 295 | 295 | 195 |
| 45,000 | 50,000 | 300 | 300 | 300 | 200 |
| 50,000 | 100,000 | 375 | 375 | 375 | 250 |
| 100,000 | 150,000 | 450 | 450 | 450 | 300 |
| 150,000 | 200,000 | 525 | 525 | 525 | 350 |
| 200,000 | 250,000[1] | 600 | 600 | 600 | 400 |
| 250,000 | 300,000 | 675 | 675 | 675 | 450 |
| 300,000 | 350,000 | 750 | 750 | 750 | 500 |
| 350,000 | 400,000 | 825 | 825 | 825 | 550 |
| 400,000 | 450,000 | 900 | 900 | 900 | 600 |
| 450,000 | 500,000[2] | 975 | 975 | 975 | 650 |

1. Maximum quantity permitted in a single aboveground magazine or operating building. Distances in columns 3 through 6 apply to unbarricaded magazines. If the magazines or operating buildings are barricaded, the quantity of powder may be limited in accordance with the unbarricaded class 2 distances but the maximum quantity shall not exceed 250,000 pounds, except as provided in paragraph 19a of T.O. 11A-1-37.

Distances in column 6 are applicable between all operating buildings and/or service magazines in a single line or area within the plant boundary and are applicable between magazines in storage areas.

Distances shown in column 3 are applicable between separate operating lines or areas except as provided in paragraph 21f of T.O. 11A-1-37.

2. Maximum quantity permitted in an igloo or corbetta-type magazine.

## Class 3 Quantity-Distance Items

Materials in this class if accidentally initiated explode progressively, not more than a box or two at a time. Pressures which will cause structural damage to adjacent magazines usually are not generated. Missiles are small and light and usually fall within 100 yards. Table III shows quantity-distance relationships of class 3 items, which consist of the following:

1. Cartridges for cartridge-actuated devices for aircraft use, when stored separately.

2. Charge, igniter, assembly, for fuze M10 and M10A1.

3. Fuzes, proximity, packed in accordance with approved drawings. These items are in class 6 when not packed in accordance with approved drawings.

3.1 Fuses with boosters fitted thereto, when packed in accordance with approved drawings and which as a result of hazard tests, have been reclassified as class 3. The following fuzes have been so reclassified for storage and shipment:

| PD | PD | MTSQ | MT | TSQ |
|---|---|---|---|---|
| M51-series | M508 | M500-series | M43-series | M55-series |
| M78-series | T177-series | M502-series | M61-series | |
| M81-series | | M506 | M67-series | |
| M507 | | M518 | | |

4. Fuzes, without boosters fitted thereto.

5. Grenades, practice, with spotting charge.

6. Igniters for rockets (e.g.,M12, M18 and M20).

7. Igniters, JATO, electric. (Except those types listed as class 10).

8. Mines, practice, with spotting charge and/or fuze.

9. Primers, artillery and cannon.

10. Primer detonators.

TABLE III - CLASS 3 QUANTITY-DISTANCE

| Quantity | Distance (feet) | | | |
|---|---|---|---|---|
| Pounds of explosive (not over) | Inhabited Building | Public Railway | Public Highway | Magazine |
| 40,000 | 400 | 400 | 400 | 300 |

## Class 4 Quantity-Distance Items

Materials in this class usually explode progressively, a few boxes at a time, when accidentally initiated. Many explosions of individual rounds would be of low order. Items in this class must be packed in accordance with approved ordnance drawings and specifications. Table IV shows quantity-distance relationships of class 4 items, which consist of the following:

1. Ammunition, blank and saluting, cannon.
2. Ammunition, caliber 20-mm or less HE and HE-I and 20-mm incendiary rounds.
3. Ammunition, fixed and semifixed, inert projectiles and those loaded with Ammonal, Amatol, Composition B, Explosive D, TNT or Baratol.
4. Bombs, chemical loaded, with explosive burster.
5. Chemical ammunition, of groups A, B, C and D, fixed and semifixed or separate-loading chemical filled items assembled with explosive bursters.
6. Mines, antipersonnel (bounding type).
7. Rocket, chemical, complete round.
8. Rocket, practice--inert head.
9. Rocket motors (exclusive of heads).
10. Shell, illuminating, complete round.
11. Shell, light mortar, 81-mm and less (excluding 81-mm M56).

   NOTE: When items in this class (except chemical) are not packed in accordance with approved ordnance drawings, the Class 10 Quantity-Distance Table will be used to compute distances.

TABLE IV - CLASS 4 QUANTITY-DISTANCE

| Quantity | Distance (feet) | | | |
|---|---|---|---|---|
| Pounds of explosive (not over) | Inhabited Building | Public Railway | Public Highway | Magazine |
| 500,000 | 1,200 | 1,200 | 1,200 | 300 |

## Class 5 Quantity-Distance Items

Materials in this class if accidentally initiated usually explode one shell at a time, and in nearly all cases, with low order. The projectiles are limited as to number and range and most of them fall within 400 yards. Items included in class 5 consist of separate-loading shells loaded with Explosive D and any other Explosive D loaded shell not assembled to or packed with cartridge cases. Table V shows quantity-distance relationships of class 5 items.

TABLE V - CLASS 5 QUANTITY-DISTANCE

| Quantity | Distance (feet) | | | |
|---|---|---|---|---|
| Pounds of explosive (not over) | Inhabited Building | Public Railway | Public Highway | Magazine |
| 650,000 | 1,200 | 1,200 | 1,200 | 300 |

## Class 6 Quantity-Distance Items

Materials in this class if accidentally initiated usually explode progressively by stacks. Missiles are light and usually fall within 200 yards. Table VI shows quantity-distance relationship of class 6 items which consist of the following:

1. Adapter--boosters,

2. Boosters.

3. Fuzes, chemically actuated, containing ampoules which may initiate, directly or indirectly, explosives and explosive loaded components which are assembled in the conventional manner to form the finished explosive fuze.

4. Fuzes, proximity, not packed in accordance with approved drawings. When these items are packed in accordance with approved drawings they are considered in class 3.

5. Fuzes, with boosters assembled thereto. For exceptions, see item 3.1 of Quantity-Distance Class 3.

6. Mines, APERS, NM, M14, with integral fuze.

   NOTE: See paragraph 21c(3) of T.O. 11A-1-37 for special requirements in the storage of items in class 6.

TABLE VI - CLASS 6 QUANTITY-DISTANCE

| Quantity | Distance (feet) | | | |
|---|---|---|---|---|
| Pounds of explosive (not over) | Inhabited Building | Public Railway | Public Highway | Magazine |
| 100,000 | 1,500 | 900 | 450 | 300 |

## Class 7 Quantity-Distance Items

Materials in this class may detonate in high order if involved in a fire. If one (1) item in a stack is detonated, the detonation en masse of the entire stack may also be expected. Structural damage may be severe and the missile hazard may extend to 1,800 feet or more. An initial explosion of class 7 items can be confined to one (1) stack if ample distances are maintained between adjacent stacks. If a detonation occurs in one (1) stack, adjacent stacks can be expected to be disarranged and scattered. Then, should a second detonation occur, propagation through the disarranged stacks could be expected. Items included in class 7 consist of separate-loading shell, fuzed or unfuzed, loaded with Ammonal, Amatol, or TNT, (except shell, HE, for 280-mm gun). Table VII shows quantity-distance relationship of class 7 items.

NOTE: See paragraph 21c(3) of T.O. 11A-1-37 for special requirements when storing class 7 items.

TABLE VII - CLASS 7 QUANTITY-DISTANCE

| Quantity | Distance (feet) | | | |
|---|---|---|---|---|
| Pounds of explosive (not over) | Inhabited Building | Public Railway | Public Highway | Magazine |
| 500,000 | 1,800 | 1,800 | 1,800 | 300 |

## Class 8 Quantity-Distance Items

Materials in this class are expected to detonate en masse if involved in a fire. Principal damage is usually due to blast or shock effect as the missiles are light and limited in range. Table VIII shows quantity-distance relationships of class 8 items, which consist of the following items when packed in accordance with approved ordnance drawings and specifications:

1. Blasting caps.
2. Detonators.
3. Percussion elements.
4. Primers, electric.

TABLE VIII - CLASS 8 QUANTITY-DISTANCE

| Quantity of explosives | | Unbarricaded distance in feet* | | | |
|---|---|---|---|---|---|
| Pounds (over) | Pounds (not over) | Inhabited Building Distance | Public Railway Distance | Public Highway Distance | Magazine Distance |
| 500 | 1,000 | 720 | 430 | 220 | 180 |
| 1,000 | 1,500 | 860 | 520 | 260 | 200 |
| 1,500 | 2,000 | 980 | 590 | 300 | 300 |
| 2,000 | 5,000 | 1,200 | 720 | 360 | 300 |
| 5,000 | 10,000 | 1,500 | 900 | 450 | 300 |
| 10,000 | 15,000 | 1,610 | 970 | 490 | 300 |
| 15,000 | 20,000 | 1,740 | 1,040 | 520 | 300 |

* These distances may be halved when requirements of paragraph 18 of T.O. 11A-1-37 are complied with.

NOTE: For quantities less than 500 pounds of explosives, the class 10 table distance shall be applied.

## Class 9 Quantity-Distance Items

If involved in a fire, black powder burns with explosive rapidity. High explosives and class 9 solid propellants may burn or explode, depending upon the material, quantity and degree of confinement. Table IX shows quantity-distance relationships of class 9 items, which consist of the following:

1. Black powder, in charges or containers.
2. Charges, supplementary (HE).
3. Composition A, A-2 and A-3.
4. Composition B.
5. Composition C, C-2 and C-3.
6. Cyclotol.
7. Dynamite.
8. EC powder.
9. Explosive D.
10. Explosives, cratering.
11. Flash reducers (black powder with potassium sulfate).
12. Lead azide.
13. Lead styphnate.
14. Mercury fulminate.
15. Minol.
16. Nitroglycerin.
17. Nitroguanadine.
18. Nitrostarch.
19. Pentolite.
20. PETN.
21. Photoflash powder.
22. Picric acid.
23. Propellants, solid (class 9).

a. Double-base with web thickness of less than 0.0075 inch regardless of nitroglycerin content.

b. Double-base containing more than twenty (20) per cent nitroglycerin.

c. Solid propellants for JATOS and rockets.

24. Pyrotechnic materials

a. In addition to individual class 9 items, such as items (1), (11) and (21) above and (28) below, pyrotechnic materials include illuminating, photoflash, flare, signal, tracer, igniter or explosive incendiary and first fire compositions up to and including final pressing or consolidating operations and including unassembled pelleted material and rejected composition held for reworking.

b. Flashlight powder.

c. Quickmatch.

25. RDX.

26. TNT.

27. Tetryl.

28. Zirconium powder (particle sizes less than twenty (20) mesh, U.S. standard sieve).

Class 10 Quantity-Distance Items

If involved in a fire, class 10 ammunition may be expected to detonate in high order and all the ammunition in one (1) magazine may detonate en masse simultaneously. Table IX shows quantity-distance relationships of class 10 items, which consist of the following:

1. Ammunition, fixed and semifixed, loaded with high explosives other than Ammonal, Amatol, Composition B, Explosive D, TNT or Baratol.

2. Ammunition, separate loading, loaded with high explosives other than Ammonal, Amatol, TNT, Explosive D or Baratol.

3. Bangalore torpedoes.

4. Bombs, demolition.

5. Bombs, fragmentation. Class 10 distances are observed, however, no distance shall be less than that required for class 4 ammunition.

6. Bombs, photoflash, w/burster (bomb, photoflash, MI22, w/o burster, is in class 2).

7. Boosters, auxiliary.

8. Bursters.

9. Cartridge, photoflash.

10. Charge, springing, earth rod, blast driven.

11. Demolition blocks.

12. Demolition charges, snake.

13. Destructor, HE, M10.

14. Firecracker, M80.

15. Grenades, fragmentation.

16. Grenades, hand offensive.

17. Grenades, rifle, AT.

18. Igniters, JATO, electric (such as M29).

19. JATOS, complete rounds.

20. Mines, antipersonnel (cast iron block).

21. Mines, HEAT.

22. Rocket heads, HE loaded.

23. Rocket, HE, complete rounds.

24. Shaped charges (Engineers).

25. Shell, HE, for 280-mm gun.

26. Shell, HE, heavy mortar, over 81-mm (including 81-mm M56).

27. Class 4 items (except chemical) not packed in accordance with ordnance drawings.

28. Classes 6 and 7 items not stacked in accordance with ordnance drawings.

## TABLE IX - CLASSES 9 AND 10 QUANTITY-DISTANCE

| Quantity of explosives | | Unbarricaded distance in feet[a] | | | | |
|---|---|---|---|---|---|---|
| Pounds (over) | Pounds (not over) | Inhabited Building Distance | Public Railway Distance | Public Highway Distance | Magazine Distance[b] | Intraline Distance |
| | 10 | 145 | 90 | 45 | 60 | |
| 10 | 25 | 145 | 90 | 45 | 60 | 40 |
| 25 | 50 | 145 | 90 | 45 | 60 | 60 |
| 50 | 100 | 240 | 140 | 70 | 80 | 80 |
| 100 | 200 | 360 | 220 | 110 | 100 | 100 |
| 200 | 300 | 520 | 310 | 150 | 120 | 120 |
| 300 | 400 | 640 | 380 | 190 | 130 | 130 |
| 400 | 500 | 720 | 430 | 220 | 140 | 140 |
| 500 | 600 | 800 | 480 | 240 | 150 | 150 |
| 600 | 700 | 860 | 520 | 260 | 160 | 160 |
| 700 | 800 | 920 | 550 | 280 | 165 | 170 |
| 800 | 900 | 980 | 590 | 300 | 170 | 180 |
| 900 | 1,000 | 1,020 | 610 | 310 | 190 | 190 |
| 1,000 | 1,500 | 1,060 | 640 | 320 | 210 | 210 |
| 1,500 | 2,000 | 1,200 | 720 | 360 | 230 | 230 |
| 2,000 | 3,000 | 1,300 | 780 | 390 | 260 | 260 |
| 3,000 | 4,000 | 1,420 | 850 | 420 | 280 | 280 |
| 4,000 | 5,000 | 1,500 | 900 | 450 | 300 | 300 |
| 5,000 | 6,000 | 1,560 | 940 | 470 | 300 | 320 |
| 6,000 | 7,000 | 1,610 | 970 | 490 | 300 | 340 |
| 7,000 | 8,000 | 1,660 | 1,000 | 500 | 300 | 360 |
| 8,000 | 9,000 | 1,700 | 1,020 | 510 | 300 | 380 |
| 9,000 | 10,000[c] | 1,740 | 1,040 | 520 | 300 | 400 |
| 10,000 | 15,000 | 1,780 | 1,070 | 530 | 300 | 450 |
| 15,000 | 20,000 | 1,950 | 1,170 | 580 | 300 | 490 |
| 20,000 | 25,000 | 2,110 | 1,270 | 630 | 300 | 530 |
| 25,000 | 30,000 | 2,260 | 1,360 | 680 | 300 | 560 |
| 30,000 | 35,000 | 2,410 | 1,450 | 720 | 300 | 590 |
| 35,000 | 40,000[d] | 2,550 | 1,530 | 760 | 300 | 620 |

TABLE IX - CLASSES 9 AND 10 QUANTITY-DISTANCE (Continued)

| Quantity of explosives | | Unbarricaded distance in feet[a] | | | | |
|---|---|---|---|---|---|---|
| Pounds (over) | Pounds (not over) | Inhabited Building Distance | Public Railway Distance | Public Highway Distance | Magazine Distance[b] | Intraline Distance |
| 40,000 | 45,000 | 2,680 | 1,610 | 800 | 300 | 640 |
| 45.000 | 50,000[e] | 2,800 | 1,680 | 840 | 300 | 660 |
| 50,000 | 55,000 | 2,920 | 1,750 | 880 | 400 | 680 |
| 55,000 | 60,000 | 3,030 | 1,820 | 910 | 400 | 700 |
| 60,000 | 65,000 | 3,130 | 1,880 | 940 | 400 | 720 |
| 65,000 | 70,000 | 3,220 | 1,940 | 970 | 400 | 740 |
| 70,000 | 75,000 | 3,310 | 1,990 | 1,000 | 400 | 770 |
| 75,000 | 80,000 | 3,390 | 2,040 | 1,020 | 400 | 780 |
| 80,000 | 85,000 | 3,460 | 2,080 | 1,040 | 400 | 790 |
| 85,000 | 90,000 | 3,520 | 2,120 | 1,060 | 400 | 800 |
| 90,000 | 95,000 | 3,580 | 2,150 | 1,080 | 400 | 820 |
| 95,000 | 100,000 | 3,630 | 2,180 | 1,090 | 400 | 830 |
| 100,000 | 125,000 | 3,670 | 2,200 | 1,100 | 800 | 900 |
| 125,000 | 150,000 | 3,800 | 2,280 | 1,140 | 800 | 950 |
| 150,000 | 175,000 | 3,930 | 2,360 | 1,180 | 800 | 1,000 |
| 175,000 | 200,000[f] | 4,060 | 2,440 | 1,220 | 800 | 1,050 |
| 200,000 | 225,000 | 4,190 | 2,520 | 1,260 | 800 | 1,100 |
| 225,000 | 250,000[g] | 4,310 | 2,590 | 1,300 | 800 | 1,150 |

[a]These distances may be halved when barricades are provided as explained in Par. 18 of T.O. 11A-1-37.

[b]Spacing of magazines other than igloo-type shall be in accordance with applicable quantity-distance tables and blocks of these magazines shall not contain more than 100 magazines.

[c]Maximum poundage of pyrotechnic materials recommended at any one location in an operating line.

[d]Maximum poundage of pyrotechnic materials permitted at any one location in an operating line.

[e]Maximum poundage of military pyrotechnics recommended for storage at any one location.

[f]Maximum poundage of military pyrotechnics permitted for storage at any one location.

[g]Maximum poundage permitted in any one magazine without special authorization.

## Class 11 Quantity-Distance Items

No quantity-distance tables are established for class 11 items, inasmuch as the items assigned to class 11 are not considered explosive hazards. The following items are included in class 11:

1. Chemical ammunition, groups A and B, when not assembled with explosive components.

2. Rocket heads, chemically loaded, except groups C and D, when not assembled with explosive components.

## Class 12 Quantity-Distance Items

The items included in class 12 are considered relatively insensitive and can normally be detonated only by very strong initiation. The applicable quantity-distance tables to be used in the handling and storage of the items in class 12 shall be governed by the actual physical location selected for the items with respect to adjacent detonation or fire hazard materials. (See requirements listed in par. 21C(3)(c) or T.O. 11A-1-37). The following items are included in class 12:

1. Ammonium nitrate.

2. DNT.

3. Nitrocellulose, wet, containing from 8 to 30 per cent water.

4. Detonating cord.

TABLE 1-1

GENERAL CLASSIFICATION OF EXPLOSIVES AND AMMUNITION

ITEMS WITH FIRE SYMBOLS INCLUDED

TABLE 1-1 GENERAL CLASSIFICATION OF EXPLOSIVES AND AMMUNITION ITEMS WITH FIRE SYMBOLS INCLUDED

| ITEM | STORAGE COMPATIBILITY GROUP | QUANTITY-DISTANCE CLASS | ICC CLASS | COAST GUARD CLASS | NAVY SERIAL ORDER | FIRE SYMBOL |
|---|---|---|---|---|---|---|
| Aluminum Powder | C | 1 | B | II-C | F.S. | 1 |
| Amatol | I | 9 | A | IX-B | t | 4 |
| Ammonium Nitrate | D | 12 | A | IX-B | t | 1 |
| Ammunition, small-arms with explosive bullets | E | 4 | A | IV-B | f | 4 |
| Ammunition, small-arms without explosive bullets | B,E and N | 1 | C | I | a | 1 |
| Black Powder | O | 9 | A | IX-A | s | 4 |
| Blasting Caps | P | 8 | A or C | VIII | k | 4 |
| Bombs, Photoflash | Q | 10 | A | X-A | V/B | 4 |
| Boosters, Adapter | B | 6 or 10 | A | X | Hh | 4 |
| Boosters, Auxiliary | B | 6 or 10 | A | X | Lt,Lv | 4 |
| Bursters | B | 6 or 10 | A | IX-A or X | Ls,Lt,Lv | 4 |
| Composition A,A-2 and A-3 | I | 9 | A | IX-B | t | 4 |
| Composition B | I | 9 | A | IX-B | t | 4 |

TABLE 1-1 GENERAL CLASSIFICATION OF EXPLOSIVES AND AMMUNITION ITEMS WITH FIRE SYMBOLS INCLUDED (Continued)

| ITEM | STORAGE COMPATIBILITY GROUP | QUANTITY-DISTANCE CLASS | ICC CLASS | COAST GUARD CLASS | NAVY SERIAL ORDER | FIRE SYMBOL |
|---|---|---|---|---|---|---|
| Composition C,C-2 and C-3 | I | 9 | A | IX-B | t | 4 |
| Cyclotol | I | 9 | A | IX-B | t | 4 |
| Demolition blocks | I | 10 | A | IX-B | u | 4 |
| Destructor, HE, Universal, M10 | B | 10 | A | VIII | v | 4 |
| Detonators, All Types | P | 8 | A | VIII | k | 4 |
| Detonating Cord, Primacord (PETN) | I | 12 | C | I | Ou | 1 |
| DNT (Dinitrotoluene) | D | 12 | A | IX-B | t | 1 |
| Dynamite | A | 9 | A | IX-B | t | 4 |
| Ednatol | I | 9 | A | IX-B | t | 4 |
| Explosive D (Ammonium Picrate) | I | 9 | A | IX-B | t | 4 |
| Firing Device w/o Detonator | B,E and N | 1 | C | I | Hh,Ha | 1 |
| Flares, All Types | N | 2 | B | II-C | c | 3 |
| Fuse, Safety | B,E and N | 1 | C | I | Oc | 1 |

TABLE 1-1 GENERAL CLASSIFICATION OF EXPLOSIVES AND AMMUNITION ITEMS WITH FIRE SYMBOLS INCLUDED (Continued)

| ITEM | STORAGE COMPATIBILITY GROUP | QUANTITY-DISTANCE CLASS | ICC CLASS | COAST GUARD CLASS | NAVY SERIAL ORDER | FIRE SYMBOL |
|---|---|---|---|---|---|---|
| Fuzes, VT (packed in accordance with approved drawings) and fuzes without boosters, except fuzes chemically actuated containing ampoules which may initiate, directly or indirectly, explosives and explosive-loaded components which are assembled in the conventional manner to form the finished explosive fuze. | B | 3 | C | III | Hh | 2 |
| Fuzes, VT (not packed in accordance with approved drawings) | B | 6 | A | VI | Hh | 4 |
| Fuzes with boosters, except fuzes VT and fuzes chemically actuated containing ampoules which may initiate, directly or indirectly explosives and explosive-loaded components which are assembled in the conventiona manner to form the finished explosive fuze. | B | 6 or 10 | A | VI | Hh | 4 |

TABLE 1-1 GENERAL CLASSIFICATION OF EXPLOSIVES AND AMMUNITION ITEMS WITH FIRE SYMBOLS INCLUDED (Continued)

| ITEM | STORAGE COMPATIBILITY GROUP | QUANTITY-DISTANCE CLASS | ICC CLASS | COAST GUARD CLASS | NAVY SERIAL ORDER | FIRE SYMBOL |
|---|---|---|---|---|---|---|
| Fuzes, chemically actuated, containing ampoules which may initiate, directly or indirectly, explosives and explosive-loaded components which are assembled in the conventional manner to form the finished explosive fuze. | A | 6 or 10 | A | VIII | Hh | 4 |
| Grenades, fragmentation | E and G | 10 | A | IV-B | Gf | 4 |
| Grenades, hand offensive | I | 10 | A | IV-B | Gu,Gt | 4 |
| Grenades, illuminating | N | 2 | C | II-C | Gc | 3 |
| Grenades, Hand, Practice | E | 3 | A | IV-B | Ga | 2 |
| Igniters for rockets (e.g., M12,M18,M20, etc.) | B | 3 | B or C | III | Oa,Hh | 2 |
| Igniters, JATO, electric (except types such as M29) | B | 3 | B or C | X | Oa,Hh | 2 |
| Igniters, JATO, electric (such as M29) | O | 10 | B | X | Oa,Hh | 4 |

TABLE 1-1 GENERAL CLASSIFICATION OF EXPLOSIVES AND AMMUNITION ITEMS WITH FIRE SYMBOLS INCLUDED (Continued)

| ITEM | STORAGE COMPATIBILITY GROUP | QUANTITY-DISTANCE CLASS | ICC CLASS | COAST GUARD CLASS | NAVY SERIAL ORDER | FIRE SYMBOL |
|---|---|---|---|---|---|---|
| JATOS, complete rounds | F | 10 | A | X-A | e/j | 4 |
| Lead Azide | M | 9 | A | IX-C | t | 4 |
| Lead Styphnate | M | 9 | A | IX-C | t | 4 |
| Mercury Fulminate | M | 9 | A | IX-C | t | 4 |
| Minol | I | 9 | A | IX-B | t | 4 |
| Missiles or rockets completely assembled, with solid fuel motors | F | 10 | A | X-C | e/j | 4 |
| Nitrocellulose, wet | M | 12 | A | | t | 1 |
| Nitroglycerin | | 9 | High explosive liquid | XI-C | t | 4 |
| Nitroguanidine | I | 12 | A | IX-B | t | 4 |
| Nitrostarch | I | 9 | A | IX-B | t | 4 |
| PETN (wet) | M | 9 | A | IX-C | t | 4 |
| Picric Acid, dry or wet | I | 9 | A | IX-B | t | 4 |
| Primer Detonators | B | 3 | C | I or III | Ja | 2 |

TABLE 1-1 GENERAL CLASSIFICATION OF EXPLOSIVES AND AMMUNITION ITEMS WITH FIRE SYMBOLS INCLUDED (Continued)

| ITEM | STORAGE COMPATIBILITY GROUP | QUANTITY-DISTANCE CLASS | ICC CLASS | COAST GUARD CLASS | NAVY SERIAL ORDER | FIRE SYMBOL |
|---|---|---|---|---|---|---|
| Primers, Electric | P | 8 | C | I or III | Ja | 4 |
| Pyrotechnic Materials | A,C and K | 1,2 and 9 | B or C | II-C and IX-A | c,dw,a, v/B,Gc, Ha,Hh | 1,3,4 |
| RDX (Cyclonite) | L (when dry)<br>M (when wet) | 9 | A | IX-B | t | 4 |
| Rocket Motors (exclusive of heads) | F | 4 | B | IV-A | Re | 4 |
| Squibs of all kinds | B,E and N | 1 | C | II-C | Ja,Oa | 1 |
| Tetryl | L | 9 | A | IX-B | | 4 |
| Tetrytol | I | 9 | A | IX-B | | 4 |
| Trinitrotoluene (TNT) | I | 9 | A | IX-B | | 4 |
| Trinitroxylene (TNX) | I or L | 9 | A | IX-B | | 4 |

## AIR FORCE AND ARMY GROUP SUMMARY OF STORAGE COMPATIBILITY FOR EXPLOSIVES AND AMMUNITION

## AIR FORCE AND ARMY GROUP SUMMARY OF STORAGE COMPATIBILITY FOR EXPLOSIVES AND AMMUNITION[1]

### GROUP A--Separate Storage[2]

Ammunition, pentolite loaded [except pentolite-loaded rifle grenades (other than the grenades listed below) and rockets].

Chemical ammunition, group A chemical agents.

Chemical ammunition, group B chemical agents.

Chemical ammunition, group C chemical agents.

Chemical ammunition, group D chemical agents.

Dynamite.

Fuzes, chemically actuated (see exceptions in Table 1-1, "General Classification of Explosives and Ammunition Items With Fire Symbols Included").

Grenades, rifle, AT, pentolite loaded.

Photoflash powder.

Pyrotechnic materials except items in groups C and K in this Table (see par. 22a and Tables III and XI of T.O. 11A-1-37).

Shell, separate, fuzed or unfuzed, all calibers, loaded with Explosive D.

Shell, separate, fuzed or unfuzed, all calibers, loaded with any HE other than Explosive D.

---

1. Explosives and ammunition are divided into seventeen (17) storage compatibility groupings based on: (a) the effects of the explosion of the item, (b) the rate of deterioration, (c) the sensitivity to initiation, (d) the type of packing, (e) the effects of fire involving the item and (f) the quantity of explosive per unit.

2. Items of this group must be stored alone.

## GROUP B[3]

Adapter-boosters.

Ammunition, caliber 20-mm or less, except HE and/or HE-I rounds and 20-mm incendiary rounds.

Boosters.

Boosters, auxiliary.

Bursters.

Cartridges, CAD.

Cartridge-actuated devices.

Charge, igniter, assembly, for fuze, M10 and M10A1.

Charge, spotting, AP, practice, M8.

Charges, supplementary.

Corporal, actuator, assembly propellant valve, quick release.

Destructor, HE, M10.

Firing devices.

Fuse lighters.

Fuse, safety.

Fuzes, with booster, except chemically actuated (see Table 1-1, for inclusion of certain types of chemically actuated fuzes).

Fuzes, without booster, except chemically actuated.

Ignition cartridges for mortar ammunition.

Igniters for rockets (M12, M18, M20, etc.).

Igniters (electric) for JATOS (class 3).

Mines, APERS, NM, M14.

Primers, cannon and artillery.

Primer-detonators.

Squibs, commercial.

---

[3] Items in Groups B through Q may be stored with other items within the individual group in any combination.

## GROUP C

Aluminum powder.

Magnesium powder.

Zirconium powder (class 1).

## GROUP D

Ammonium nitrate.

DNT.

## GROUP E

Ammunition, blank and saluting, cannon.

Ammunition, caliber 20-mm or less.

Ammunition, fixed and semifixed, except chemical and pentolite loaded ammunition.

Firing devices.

Fuse lighters.

Fuse, safety.

Grenades, hand fragmentation and practice with spotting charge.

Ignition cartridges for mortar ammunition.

Mines, AP (bounding type).

Mines, practice, with fuze and/or spotting charge.

Projectiles, illuminating.

Shell, illuminating, complete round.

Shell, light mortar, 81-mm or less (excluding 81-mm M56), except chemical loaded.

Squibs, commercial.

## GROUP F

JATOS, complete rounds.

Rockets, HE, complete rounds.

Rockets, practice.

Rocket motors.

Rocket heads, HE (without motor).

## GROUP G

Bangalore torpedoes.

Bombs, demolition.

Bombs, fragmentation.

Rocket heads, HE (without motor, except pentolite loaded).

Mines, AP (cast iron block).

Grenades, fragmentation.

Grenades, rifle, AT (except pentolite loaded).

Shell, heavy mortar, over 81-mm (including 81-mm M56), except chemical loaded.

Snake, demolition.

Snake, mine clearing.

## GROUP H

Mines, HE, AT (to be combined with group G upon completion of replacement of chemically actuated fuzes of the M600 type).

## GROUP I

CBS (experimental propellant - 85% RDX and 15% desensitizer).

Charge, springing, earth rod.

Composition A, A-2 and A-3.

Composition B.

Composition C, C-2 and C-3.

Cyclotol (not to exceed max. 85 per cent RDX).

Demolition blocks.

Explosives, cratering.

Explosive D.

Grenades, hand offensive.

Minol.

Nitroguanadine.

Nitrostarch.

Pentolite.

Picric acid.

Primacord.

Shaped charges.

TNT.

Supplementary charges.

GROUP J

Charges, propelling.

EC powder in bulk.

Propellants, solid (class 2).

Propellants, solid (class 2A).

Propellants, solid (class 9).

GROUP K

Chlorates.

Nitrates (inorganic).

Perchlorates.

Peroxides, solid.

GROUP L

Cyclonite (RDX).

Tetryl.

GROUP M

Lead azide, wet.

Lead styphnate, wet.

Mercury fulminate, wet.

PETN, wet.

Zirconium powder, wet.

RDX (wet).

Nitrocellulose (wet).

GROUP N

Ammunition, caliber 20-mm, or less, except HE and/or HE-I and 20-mm incendiary rounds.

Bail, cellulose nitrate, powder-filled.

Charge, spotting, AP, practice, M8.

Corporal, actuator, assembly propellant valve, quick release.

Firing devices.

Fuse lighters.

Fuse, safety.

Grenades, illuminating.

Ignition cartridges for mortar ammunition.

Military pyrotechnics except items in this classification listed separately in Groups A and M of this Table.

Projectiles, illuminating, without propellant.

Simulators M110, M117, M118 and M119.

Spotting charges (cartridge for miniature practice bombs).

Squibs, commercial.

GROUP O

Black powder in charges or containers.

Black powder spotting charges.

Flash reducers (black powder with potassium sulfate).

Igniters (electric) for JATOS (class 10).

GROUP P

Blasting caps.

Detonators.

Percussion elements.

Primers, electric.

GROUP Q

Firecracker M80.

Photoflash bomb.

Photoflash cartridges.

Simulators, M115 and M116.

**TABLE 1-2**

**LOADING AND STORAGE CHART OF**

**EXPLOSIVES**

**AND OTHER DANGEROUS ARTICLES**

## TABLE 1-2 - LOADING AND STORAGE CHART OF EXPLOSIVES

## AND OTHER DANGEROUS ARTICLES*

The following table shows the explosives and other dangerous articles which must not be loaded or stored together.

The letter X at an intersection of horizontal and vertical columns shows that these articles must not be loaded or stored together. For example: Detonating fuses, class A, with or without radioactive components g horizontal column must not be loaded or stored with high explosives or propellant explosives, class A, b vertical column.

| | | Low explosives or black powder | High explosives or propellant explosives, class A | Initiating or priming explosives, wet: Diazodinitrophenol, fulminate of mercury, guanyl nitrosamino guanylidene hydrazine, lead azide, lead styphnate, nitro mannite, nitrosoguanidine, pentaerythrite tetranitrate, tetrazene | Blasting caps, with or without safety fuse (including electric blasting caps), detonating primers | Ammunition for cannon with explosive projectiles, gas projectiles, smoke projectiles, incendiary projectiles, illuminating projectiles or shell, ammunition for small arms with explosive bullets, or ammunition for small arms with explosive projectiles, or rocket ammunition with explosive projectiles, gas projectiles, smoke projectiles, incendiary projectiles, illuminating projectiles; and boosters (explosive), bursters (explosive), or supplementary charges (explosive), without detonators. c, d | Explosive projectiles, bombs, torpedoes, or mines, rifle or hand grenades (explosive), jet thrust units (jato), explosive, class A, or igniters, jet thrust (jato), explosive, class A c | Detonating fuses, class A with or without radioactive components | Ammunition for cannon with empty, inert-loaded or solid projectiles, or without projectiles, or rocket ammunition with empty projectiles, inert-loaded or solid projectiles or without projectiles | Propellant explosives, class B, jet thrust units (jato) class B, igniters, jet thrust (jato), class B, or starter cartridges, jet engine, class B. | Fireworks, special or railway torpedoes | Small arms ammunition | Primers for cannon or small arms, empty cartridge bags—black powder igniters, empty cartridge cases, primed, empty grenades, primed, combination primers or percussion caps, toy caps, explosive cable cutters, explosive rivets | Percussion fuses, tracer fuses or tracers | Time, combination or detonating fuses, class C | Cordeau detonant fuse, safety squibs, fuse lighters, fuse igniters, delay electric igniters, electric squibs, instantaneous fuse or igniter cord | Fireworks, common, highway fusees or railway fusees | Flammable liquids or compressed flammable gases, red label | Flammable solids or oxidizing materials, yellow label | Acids or corrosive liquids, white label | Compressed nonflammable gases, green label | Poisonous gases or liquids, in cylinders, projectiles or bombs, poison gas label | Radioactive materials (class D poisons) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | b | c | d | e | f | g | 1 | 2 | 3 | 4 | 5 | 6 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **CLASS A EXPLOSIVES** | | | | | | | | | | | | | | | | | | | | | | | |
| Low explosives or black powder | a | | | X | | | | | | | X | | | | | | X | X | X | X | X | X | X |
| High explosives or propellant explosives, class A | b | | | X | aX | | | X | | | X | | | | | | X | X | bX | X | X | X | X |
| Initiating or priming explosives, wet: Diazodinitrophenol, fulminate of mercury, guanyl nitrosamino guanylidene hydrazine, lead azide, lead styphnate, nitro mannite, nitrosoguanidine, pentaerythrite tetranitrate, tetrazene | c | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Blasting caps, with or without safety fuse (including electric blasting caps), detonating primers | d | | aX | X | | X | X | | | | aX | | | | | | aX | aX | abX | aX | aX | X | X |
| Ammunition for cannon with explosive projectiles, gas projectiles, smoke projectiles, incendiary projectiles, illuminating projectiles or shell, ammunition for small arms with explosive bullets, or ammunition for small arms with explosive projectiles, or rocket ammunition with explosive projectiles, gas projectiles, smoke projectiles, incendiary projectiles, illuminating projectiles; and boosters (explosive), bursters (explosive), or supplementary charges (explosive), without detonators. c, d | e | | | X | X | | | X | | | X | | | | | | X | X | X | X | X | X | X |
| Explosive projectiles, bombs, torpedoes, or mines, rifle or hand grenades (explosive), jet thrust units (jato), explosive, class A, or igniters, jet thrust (jato), explosive, class A c | f | | | X | X | | | X | | | X | | | | | | X | X | X | X | X | X | X |
| Detonating fuses, class A, with or without radioactive components | g | | X | X | | X | X | | | | X | | | | | | X | X | X | X | X | X | X |
| **CLASS B EXPLOSIVES** | | | | | | | | | | | | | | | | | | | | | | | |
| Ammunition for cannon with empty, inert-loaded or solid projectiles, or without projectiles, or rocket ammunition with empty projectiles, inert-loaded or solid projectiles or without projectiles | 1 | | | X | | | | | | | | | | | | | | | | aX | | X | |
| Propellant explosives, class B, jet thrust units (jato) class B, igniters, jet thrust (jato), class B, or starter cartridges, jet engine, class B | 2 | | | X | | | | | | | | | | | | | | | | aX | | X | |
| Fireworks, special or railway torpedoes | 3 | X | X | X | aX | X | X | X | | | | | | | | | | | | | | X | |

* This Chart was taken from the American Trucking Association's "Dangerous Articles Tariff No. 10"
See footnotes at end of Table

## TABLE 1-2 - LOADING AND STORAGE CHART OF EXPLOSIVES AND OTHER DANGEROUS ARTICLES (Continued)

The following table shows the explosives and other dangerous articles which must not be loaded or stored together.
The letter X at an intersection of horizontal and vertical columns shows that these articles must not be loaded or stored together, for example: Detonating fuses, class A, with or without radioactive components g horizontal column must not be loaded or stored with high explosives or propellant explosives, class A, b vertical column.

Column headings:
- a — Low explosives or black powder
- b — High explosives or propellant explosives, class A
- c — Initiating or priming explosives, wet: Diazodinitrophenol, fulminate of mercury, guanyl nitrosamino guanylidene hydrazine, lead azide, lead styphnate, nitro mannite, nitrosoguanidine, pentaerythrite tetranitrate, tetrazene
- d — Blasting caps, with or without safety fuse (including electric blasting caps), detonating primers
- e — Ammunition for cannon with explosive projectiles, gas projectiles, smoke projectiles, incendiary projectiles, illuminating projectiles or shell; ammunition for small arms with explosive bullets, or ammunition for small arms with explosive projectiles, or rocket ammunition with explosive projectiles, gas projectiles, smoke projectiles, incendiary projectiles, illuminating projectiles; and boosters (explosive), bursters (explosive), or supplementary charges (explosive), without detonators, c, d
- f — Explosive projectiles, bombs, torpedoes, or mines, rifle or hand grenades (explosive), jet thrust units (jato), explosive, class A, or igniters, jet thrust (jato), explosive, class A c
- g — Detonating fuses, class A, with or without radioactive components
- 1 — Ammunition for cannon with empty, inert-loaded or solid projectiles, or without projectiles, or rocket ammunition with empty projectiles, inert-loaded or solid projectiles or without projectiles
- 2 — Propellant explosives, class B, jet thrust units (jato) class B, igniters, jet thrust (jato), class B, or starter cartridges, jet engine, class B
- 3 — Fireworks, special or railway torpedoes
- 4 — Small arms ammunition
- 5 — Primers for cannon or small arms, empty cartridge bags—black powder igniters, empty cartridge cases, primed, empty grenades, primed, combination primers or percussion caps, toy caps, explosive cable cutters, explosive rivets
- 6 — Percussion fuses, tracer fuses or tracers
- 7 — Time, combination or detonating fuses, class C
- 8 — Cordeau detonant fuse, safety squibs, fuse lighters, fuse igniters, delay electric igniters, electric squibs, instantaneous fuse or igniter cord
- 9 — Fireworks, common, highway fusees or railway fusees
- 10 — Flammable liquids or compressed flammable gases, red label
- 11 — Flammable solids or oxidizing materials, yellow label
- 12 — Acids or corrosive liquids, white label
- 13 — Compressed nonflammable gases, green label
- 14 — Poisonous gases or liquids, in cylinders, projectiles or bombs, poison gas label
- 15 — Radioactive materials (class D poisons)

| | | a | b | c | d | e | f | g | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CLASS C EXPLOSIVES** | | | | | | | | | | | | | | | | | | | | | | | |
| Small arms ammunition | 4 | | | X | | | | | | | | | | | | | | | | | | | |
| Primers for cannon or small arms, empty cartridge bags-black powder igniters, empty cartridge cases, primed, empty grenades, primed, combination primers or percussion caps, toy caps, explosive cable cutters, explosive rivets | 5 | | | X | | | | | | | | | | | | | | | | | | | |
| Percussion fuses, tracer fuses or tracers | 6 | | | X | | | | | | | | | | | | | | | | | | | |
| Time, combination or detonating fuses, class C | 7 | | | X | | | | | | | | | | | | | | | | | | | |
| Cordeau detonant fuse, safety squibs, fuse lighters, fuse igniters, delay electric igniters, electric squibs, instantaneous fuse or igniter cord | 8 | | | X | | | | | | | | | | | | | | | | | | | |
| Fireworks, common, highway fusees or railway fusees | 9 | | X | X | aX | X | X | X | | | | | | | | | | | | | | X | |
| **OTHER DANGEROUS ARTICLES** | | | | | | | | | | | | | | | | | | | | | | | |
| Flammable liquids or compressed flammable gases, red label | 10 | X | X | X | aX | X | X | X | | | | | | | | | | | | | | X | |
| Flammable solids or oxidizing materials, yellow label | 11 | X | bX | X | abX | X | X | X | | | | | | | | | | | | bX | | X | |
| Acids or corrosive liquids, white label | 12 | X | X | X | aX | X | X | X | bX | bX | | | | | | | | | bX | | | X | |
| Compressed nonflammable gases, green label | 13 | X | X | X | aX | X | X | X | | | | | | | | | | | | | | | |
| Poisonous gases or liquids, in cylinders, projectiles or bombs, poison gas label | 14 | X | X | X | X | X | X | X | X | X | X | | | | | | X | X | X | X | | | |
| Radioactive materials (class D poisons) | 15 | X | X | X | X | X | X | X | | | | | | | | | | | | | | | |

a Blasting caps or electric blasting caps in quantities not exceeding 1,000 caps may also be loaded and transported with articles named in vertical and horizontal columns 3, 9, 10, 11, 12 and 13. Loading and transportation of blasting caps or electric blasting caps, except as prescribed in § 77.834, in any quantity, with articles named in vertical or horizontal columns b, c, e or f is prohibited.

b Acid or other corrosive liquids, white label, must not be loaded above or adjacent to flammable solids or oxidizing materials, yellow label, ammunition for cannon with or without projectiles, or propellant explosive, except that shippers loading truckload shipments of white label and yellow label packages and who have obtained prior approval from the Bureau of Explosives may load such articles together when it is known that the mixture of contents would not cause a dangerous evolution of heat or gas.

c Explosives, class A, and explosives, class B, must not be loaded or stored with chemical ammunition containing incendiary charges or white phosphorus either with or without bursting charges. Chemical ammunition of the same classification containing incendiary charges or white phosphorus may be loaded and stored together.

d Bursters (explosive), boosters (explosive), or supplementary charges (explosive) without detonators when shipped by, to or for the Departments of the Army, Navy, and Air Force of the United States Government, may be loaded with any of the articles named, except those in columns c, d, 3, 9, 10, 11, 12, 13, 14 and 15.

e Does not include nitro carbo nitrate or ammonium nitrate, fertilizer grade, which may be loaded, transported or stored with high explosives or with blasting caps or electric blasting caps, and detonating primers.

Note 1—Charged electric storage batteries must not be loaded in the same vehicle with explosives, class A.

Note 2—Cyanides or cyanide mixtures must not be loaded or stored with acids or corrosive liquids.

Note 3—Gas identification sets may be loaded and transported with all articles named except those in column c.

Note 4—Nitric acid, when loaded in the same motor vehicle with other acids or other corrosive liquids in carboys, must be separated from the other carboys. A 2 by 6 inch plank, set on edge, should be nailed across the motor vehicle floor at least 12 inches from the nitric acid carboys, and the space between the plank and the carboys of nitric acid should be filled with sand, sifted ashes, or other incombustible absorbent material.

## II. GENERAL SAFETY PRECAUTIONS

### A. Introduction

Improper handling of explosives and their accessories may cause accidents resulting in serious injuries or death to personnel and the destruction of property. The history of accidents with explosives indicates that in practically every instance these accidents could have been avoided. Therefore, the general safety precautions discussed herein shall be strictly enforced.

### B. Personnel Safety

1. Extreme care shall be exercised in the selection of personnel employed to handle explosives and ammunition. Only those physically and mentally capable of realizing their responsibilities to themselves and others shall be employed.

2. Explosives and ammunition shall be handled under the direct supervision of a competent person who understands the hazards and risks involved. Personnel handling explosives and ammunition shall be thoroughly instructed that their safety, as well as that of others, depends upon the degree of intelligence and care exercised by them when handling explosives.

3. Personnel handling explosives and ammunition must not tamper with or disassemble any components unless authorized to do so. Serious accidents may result.

4. Persons handling explosives and ammunition must clean all mud and grit from their shoes before entering the magazine, car, boat or vehicle where explosives or ammunition are contained.

5. Protective clothing and equipment furnished by PAA shall be utilized as required (see subsection entitled "Protective Clothing and Equipment," page 1-51). Clothing not worn during working hours must be placed in approved lockers in designated locations.

6. Safety shoes of the appropriate type shall be worn where operations require the handling of exposed explosives. Exposed explosives may be ignited by static discharge, friction or impact.

### C. Care and Precautions in Handling Explosives and Ammunition

1. In addition to the explosive hazard, explosives

also have varying degrees of toxicity hazard when inhaled, ingested or absorbed through the skin. Dust-air mixtures also present an additional explosion hazard. Therefore, explosives must be handled only when adequate ventilation is provided to preclude the formation of dust-air mixtures. Spark discharges of static electricity shall be prevented by the installation of proper grounding devices.

2. The inhalation of vapors of nitroglycerin or the nitrated glycols can cause severe headache. Some individuals are sensitive to very small quantities of these materials. The inhalation of the dusts or vapors of nitro-compounds such as TNT and picric acid has been known to have fatal effects on personnel. Explosives, therefore, must always be handled in adequately ventilated areas.

3. The effects caused by the contact of explosives with the skin, vary from simple discoloration to dermatitis and from headaches to poisoning. These discomforts are caused by absorption of the gaseous or liquid materials through the pores of the skin. After handling any quantity of explosives, the hands shall be washed thoroughly with soap and water. Personnel working with explosives throughout the day shall bathe themselves thoroughly and change clothes upon completion of their duty.

4. The nervous reaction of an individual working with explosives is of great concern. The extremely nervous individual and the hurried worker shall not be permitted to handle explosives. Personnel having a calm disposition and a conscientious attitude will probably maintain closer observance of standard safety regulations.

5. The number of personnel exposed and the quantity of hazardous material shall be limited to a minimum when handling ammunition.

6. All explosives or hazardous materials, regardless of type, must be handled carefully to prevent shock or friction which may cause a fire, explosion or damage to the material. Explosives and ammunition must not be thrown, dropped, walked, dragged or tumbled over the floor, over other containers or otherwise subjected to shock.

7. During the handling of explosives and ammunition, every precaution must be taken to avoid their contact with sand, earth, gravel and other abrasive or spark-producing substances.

8. Explosives and ammunition shall not be unnecessarily exposed to inclement weather nor to the direct rays of the sun.

9. Bulk explosives and ammunition in containers shall be handled in a manner to avoid rupture of the containers or the container seams and to prevent undue friction between individual containers. When a container is found in an unsatisfactory condition, its contents must be transferred to a container in a satisfactory condition that is properly labeled.

10. Explosives and ammunition shall be carefully handled in order that identification markings will not be obliterated or defaced.

11. Special care must be exercised when handling explosive containers to prevent leakage that may cause a serious hazard. This is especially important when black powder or other finely granulated explosives are being handled.

12. Packing boxes having sift-proof or water-proof linings shall be handled with care so that the linings will not be damaged.

13. Employees shall not be permitted to work alone during handling or loading operations. This rule shall apply in all cases except when specifically permitted by area supervision.

14. Steel or other spark-producing tools or equipment shall not be used when handling explosives or ammunition. Safety tools are required for opening boxes and for making repairs (see Figure 1-1). These tools are constructed of wood or non-sparking or spark-resistant materials, e.g. bronze, lead, beryllium alloys and monel metal. These materials will not produce sparks under normal conditions.

15. Gasoline-powered lift trucks shall not be used when handling exposed explosives, nor will they be used for other purposes in locations where exposed explosives are present. They must not be used inside magazines.

16. Ammunition and explosives shall not be improvised, reconditioned, renovated or salvaged within the magazine area. This rule shall apply except in cases where specific approval has authorized a site to be used exclusively for such operations. Quantity-distance requirements must be observed (see "Air Force and Army Quantity-Distance Classification of Explosives and Ammu-

FIG. 1-1: NON-SPARKING TOOLS

nition," pages 1-6 through 1-25).

17. If explosives spill or sift from a leaky container, all work will be stopped until the explosives have been removed and surfaces washed or desensitized.

D. Fire Protection

1. General

a. Fire prevention is of utmost importance. Many of the fires caused by explosives and ammunition are preventable. It shall be a primary duty of those concerned with ammunition and explosives to study the causes of fires and to be thoroughly informed of the safety precautions necessary to prevent fires.

b. Heat is extremely hazardous in and around explosives. Some explosives ignite at temperatures substantially lower than the temperature required to ignite wood, paper or fabrics. Therefore, every effort will be exerted to maintain normal temperatures surrounding ammunition and explosives in order to prevent fires and/or explosions.

2. Causes of Fires

a. Deterioration of Explosives and Ammunition

Deterioration of explosives and ammunition normally occurs at such a slow rate that most explosives and ammunition remain serviceable for many years. However, under unfavorable conditions of temperature and humidity, explosives and ammunition may produce heat so fast that it cannot be dissipated. This causes the explosive or ammunition to burst into flame or explode.

b. Repacking, Renovation and Salvage Operations, Improperly Supervised and not Conducted in Accordance with Recognized Safety Standards

The most common sources of trouble are excessive quantities of powder and loose explosives, accumulation of waste paper, broken boxes, use of spark-producing tools, defective machinery, faulty electrical equipment, etcetera. Failure to provide the proper barricades and firebreaks to prevent fires from spreading is also a frequent cause of other fires.

c. Lack of Training, Violations of Instructions and Written Regulations

The most common violations involve smoking, carrying matches in forbidden areas and buildings or tampering with explosives or ammunition, particularly grenades or fuses.

d. Failure to Understand and Carefully Observe the Safety Precautions Prescribed for Destroying Explosives and Ammunition

Grass fires caused by flying fragments may explode piles of explosives and ammunition awaiting destruction.

e. Sparks

Sparks may be caused by striking iron nails, steel nails, or metal containers with iron or steel tools. Nails in shoes striking flint, pebbles, sand grains, etcetera, may also cause sparks. Sparks have caused disastrous explosions of black powder and the dust of other explosives which ignite easily. Tools of brass, copper or other non-sparking materials are utilized in explosive operations to eliminate sparks. Cleaning mud and dirt from shoes before entering magazines and wearing approved safety shoes when exposed explosives are present are other precautions taken to prevent the occurrence of sparks.

f. Static Electricity

Charges of static electricity can be accumulated on a person and on explosive material. The discharge of static electricity is considered a serious hazard in the presence of certain exposed explosives, dust and air mixtures and inflammable vapor-air mixtures. Processing or handling equipment for these materials subjected to static discharge shall be electrically-grounded conductive material. Personnel shall be provided with authorized types of safety shoes. Cushioned-metal chairs shall not be used in locations where explosives or highly inflammable materials are present.

g. Failure to Safely Control the Use of Heat and Flame-Producing Equipment

This equipment may be the type used in maintenance work on area buildings or equipment that is contaminated with explosive material.

h. Lightning

Lightning may strike buildings, trees or other objects in or near explosive areas. All buildings and structures in ammunition and explosive storage areas shall be provided with complete lightning protection.

i. Electric Transmission Lines

Electric transmission lines are often blown down and in many cases come in contact with combustible materials.

j. Lack of a Proper Muffler

Fires may be caused by motor vehicles operating within an explosive area without a proper muffler, a muffler cut-out or an exhaust-spark arrestor.

## III. PROTECTIVE CLOTHING AND EQUIPMENT

### A. General

Protective clothing and equipment shall be selected or designed on the basis of a comprehensive study of the working conditions and personnel protection required. Additional studies shall be made of the records of accidents, safety inspections and suggestions by employees to insure that proper protection is provided.

Definite regulations regarding the utilization of protective clothing and equipment shall be established and enforced. Personnel shall be thoroughly instructed in the types, use and maintenance of protective items. Complaints from employees, regarding the wearing of protective clothing and equipment, shall be thoroughly and promptly investigated.

### B. Clothing

Employees required to wear safety uniforms or special protective clothing shall leave their personal clothing in lockers provided in the change house. A complete change of protective clothing shall be made daily. Employees shall be inspected by their supervisor prior to entering the work area to insure that they are satisfactorily attired to meet the safety requirements of their job. Silk, wool, nylon or rayon outer or under garments shall not be worn in any operation where the generation of static electricity would create a hazard.

Personnel exposed to possible flash fires and operations where their clothing may become contaminated with highly combustible materials as explosives, explosive dusts, etc., shall be provided with and shall wear flameproofed-coveralls. Clothing is flameproofed to decrease its burning characteristics and thus reduce the hazard of burns to the wearer. Flameproofed-coveralls shall also be worn in explosive operations involving black powder, smokeless powder, tracers, incendiaries, primers, pyrotechnics, igniters, tracer-igniter mixtures, fuze powders, metal powders, propellants, rocket motors, JATOS and related accessories. Personnel engaged in destroying the above-named materials shall also wear flameproofed-coveralls. All operations shall be carefully examined to determine the need of flameproofed-clothing for the personnel exposed.

All clothing contaminated with explosives shall

be laundered at a base laundry or by private laundries under contract. The frequency of laundering depends on the severity of the hazard and the degree of contact with explosives. The hazards which may be encountered shall be covered in the contract to assure against accidents or damage resulting from clothing soiled by or containing explosives. A periodic check shall be made of the efficiency with which contaminating agents are removed in the laundering processes.

Flameproofed-coveralls and other items of protective clothing and equipment are shown in Figure 1-2.

C. Safety Shoes

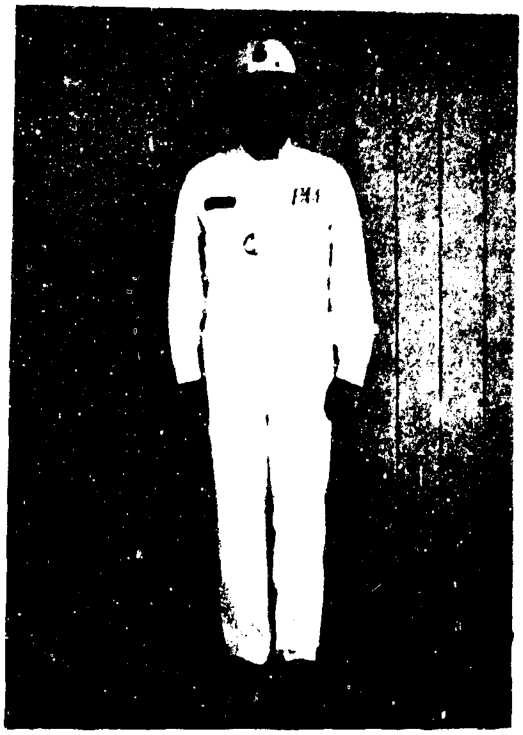
1. Semi-conductive Safety Shoes

a. Description and Use

Semi-conductive safety shoes, often referred to as "conductive" shoes, are leather shoes with semi-conductive rubber compound heels and outsoles (see Figure 1-3). The sole and heel shall be constructed to furnish a semi-conductive path from the inside of the shoe to the base of the shoe, through both the sole and the heel. The finished shoes shall contain no metallic fasteners of any kind, except in the shank, if required.

Semi-conductive shoes shall be worn by personnel in locations where the accumulation of static electricity in the body of the wearer might create a spark which could ignite sensitive explosives, gas-mixtures, pyrotechnics, incendiary mixtures or flammable vapors. Semi-conductive shoes shall be worn by personnel who walk upon conductive floors where exposed explosives are present. The preceding requirements apply not only to personnel assigned to the area but also to personnel from other departments or visitors who enter the area. Personnel or visitors entering an area where explosives are exposed shall wear semi-conductive safety shoes or other approved safety-grounding devices (see Figure 1-3). Conductive shoes lose their efficiency if worn under all conditions. Therefore, these shoes shall be worn only in specifically designated areas. Mud and dirt clog the pores of the shoes and prevent static electricity from passing into the ground.

Only cotton socks are permitted to be worn



FLAMEPROOF COVERALLS, HARD HAT AND CONDUCTIVE SHOES

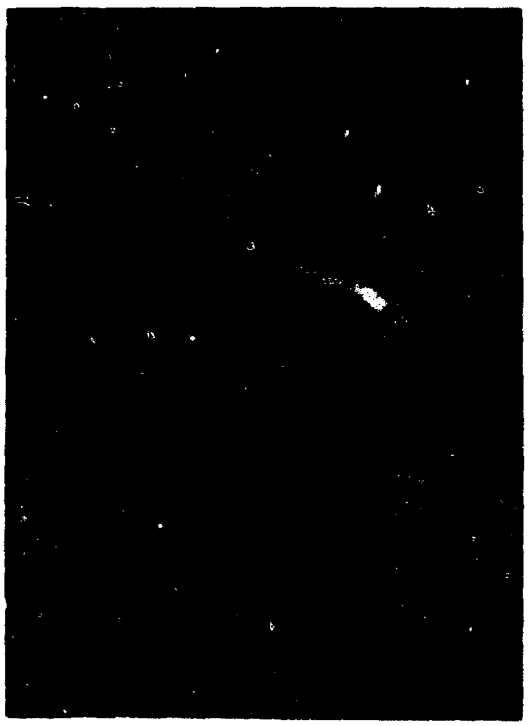
FACE SHIELD, HARD HAT, COVERALLS AND CONDUCTIVE SHOES

LEATHER APRON, GLOVES AND GOGGLES

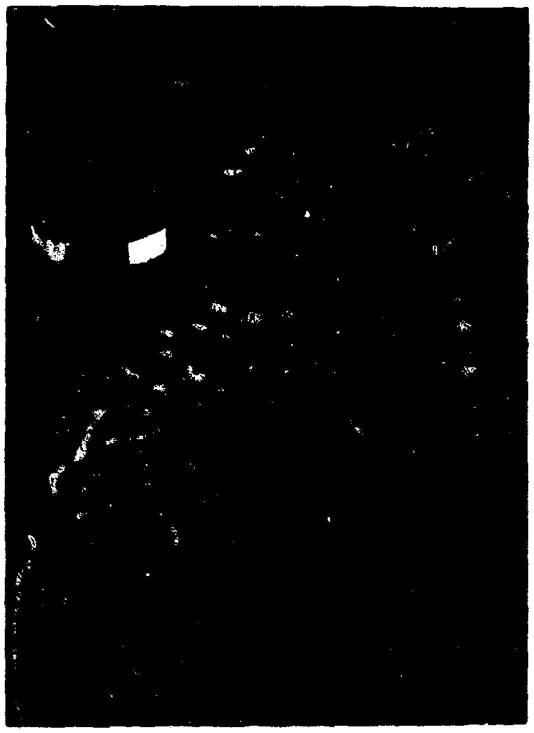
ACID SUIT

FIG. 1-2: PROTECTIVE CLOTHING AND EQUIFMENT

CONDUCTIVE SAFETY SHOE NON-CONDUCTIVE SAFETY SHOE



CONDUCTIVE GARTERS



WEARING CONDUCTIVE GARTER

FIG. 1-3: FOOT PROTECTION AND SAFETY GROUNDING DEVICE

with conductive shoes. Pads, inner soles and arch supports shall not be worn with these shoes.

Conductive shoes shall be stored in lockers close to the area in which they are to be worn. The change from non-conductive to conductive shoes shall be made in the locker room in the change house.

b. Testing

Tests of semi-conductive shoes shall be made prior to use and whenever necessary to insure that the resistance of the shoes is within the required limits. These tests shall be made while the shoes are actually worn by the employee.

A testing instrument commonly used for testing these shoes consists of two (2) conductive plates (see Figure 1-4). The instructions for operating the conductive-shoe tester may be read from a photograph in Figure 1-5. The test voltage shall be approximately ninety (90) volts and the test current in normal operation shall not exceed one (1) milliampere. No more than two (2) milliamperes shall flow across the plates. Tests shall not be performed in rooms in which explosives are present. Positive safeguards must be incorporated into the design of the instrument to eliminate all possibilities of electric shock to the person undergoing the test.

A record of tests shall be maintained where the shoe testing equipment is located. The following information shall be recorded for each shoe test:

(1) The name of the employee to whom the shoes are issued

(2) The condition of the shoes at the time of the test

(3) The resistance readings

(4) The date the test is conducted

(5) The initials of the person conducting the test.

2. Overshoes, Rubber Boots and Rubber-Soled Shoes

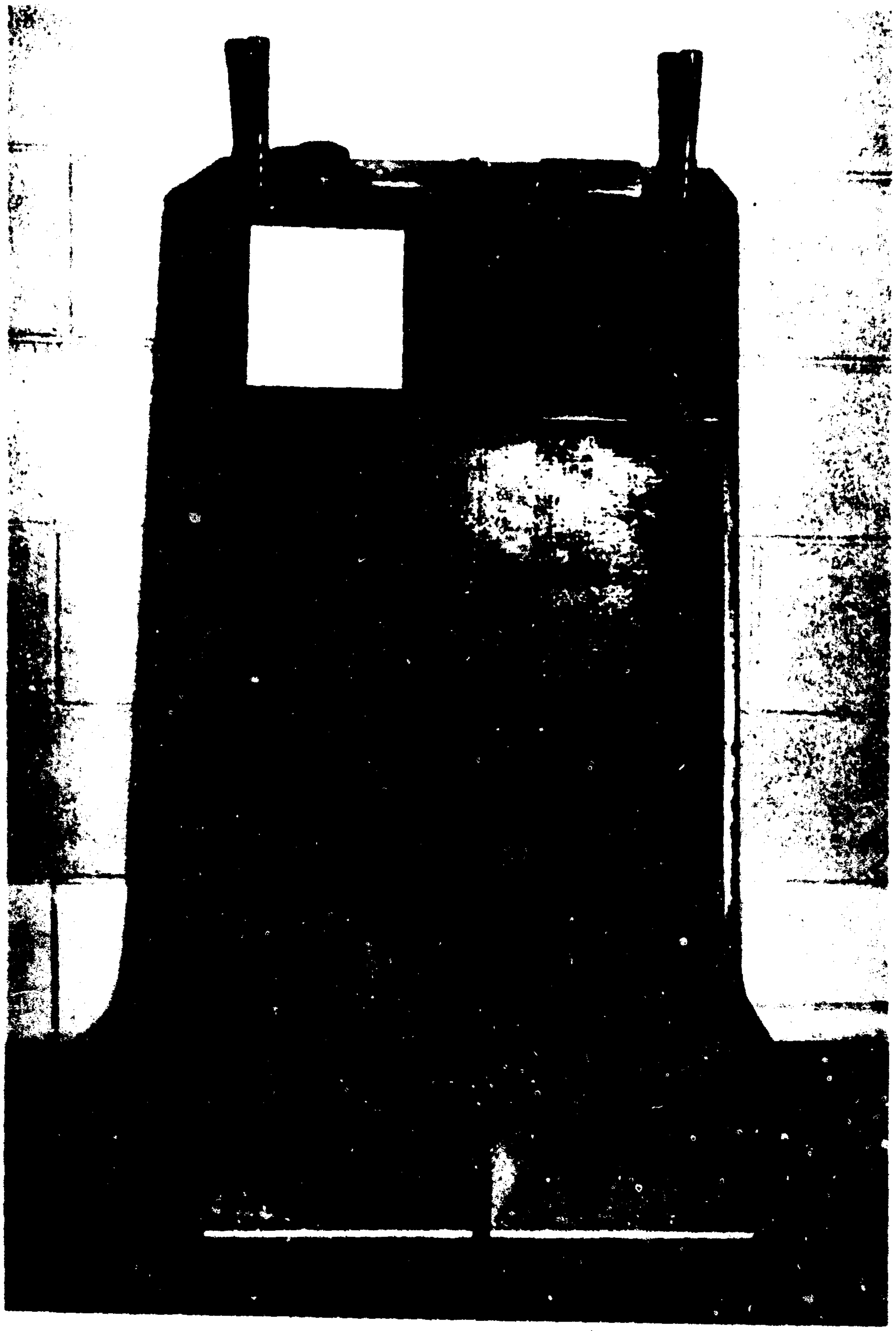
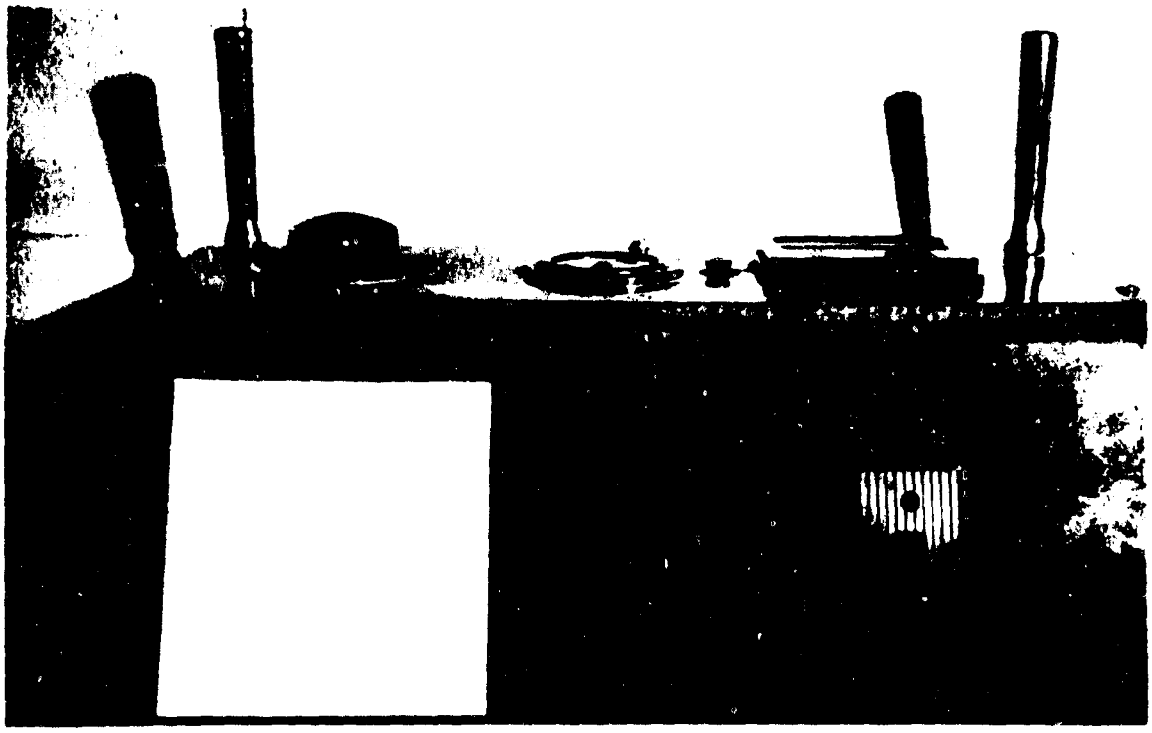
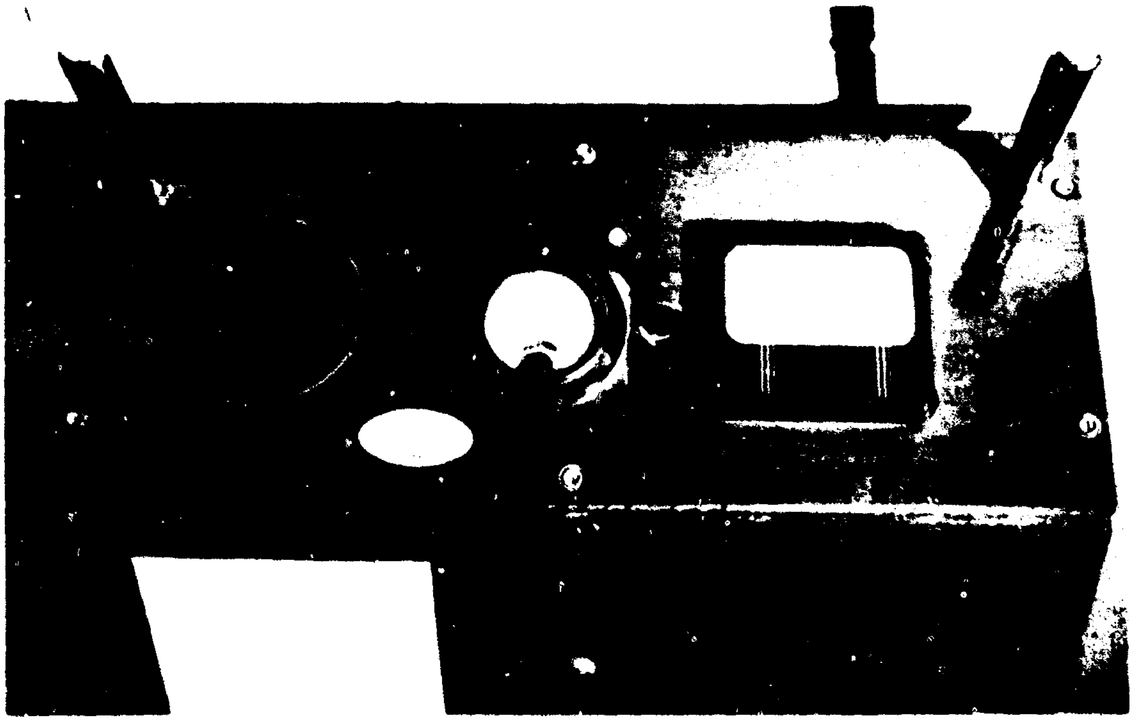


FIG. I-4: CONDUCTIVE SHOE TESTER



CONDUCTIVE SHOE TESTER - FRONT VIEW



CONDUCTIVE SHOE TESTER - TOP VIEW - PANEL

FIG. I-5: CONDUCTIVE SHOE TESTER

Overshoes, rubber boots or rubber-soled shoes that have no exposed metal may be worn in lieu of conductive-safety shoes by transients and non-regular area workers. However, these items shall not be worn where conductive footwear is required unless they pass the conductivity test.

Overshoes, rubber boots or rubber-soled shoes that have no exposed metal may be worn when necessary for cold or wet weather protection in magazines in which there are no exposed explosives, flammable fumes or dust concentrations. However, this type of footwear shall not be worn in magazines containing black powder, either exposed or in containers.

D. Perspiration Control

Operators shall wear sweatbands on their foreheads and take other precautions to avoid perspiration falling upon material, for example, metal powders and other compositions, which react with or may be ignited by moisture (see Figure 1-6).

E. Safety Goggles or Eye Shields

Approved safety goggles or eye shields shall be worn by personnel exposed to the hazards of impact, dust, bright flame or splash to prevent eye injuries (see Figure 1-6). This equipment shall be cleaned and maintained in accordance with the manufacturer's instructions. The materials in these items must not contain nitrocellulose or a similar highly flammable material. Goggles and eye shields shall be provided for and specifically assigned to individual persons. They shall not be used interchangeably among personnel unless they are thoroughly cleaned and treated antiseptically prior to reissue.

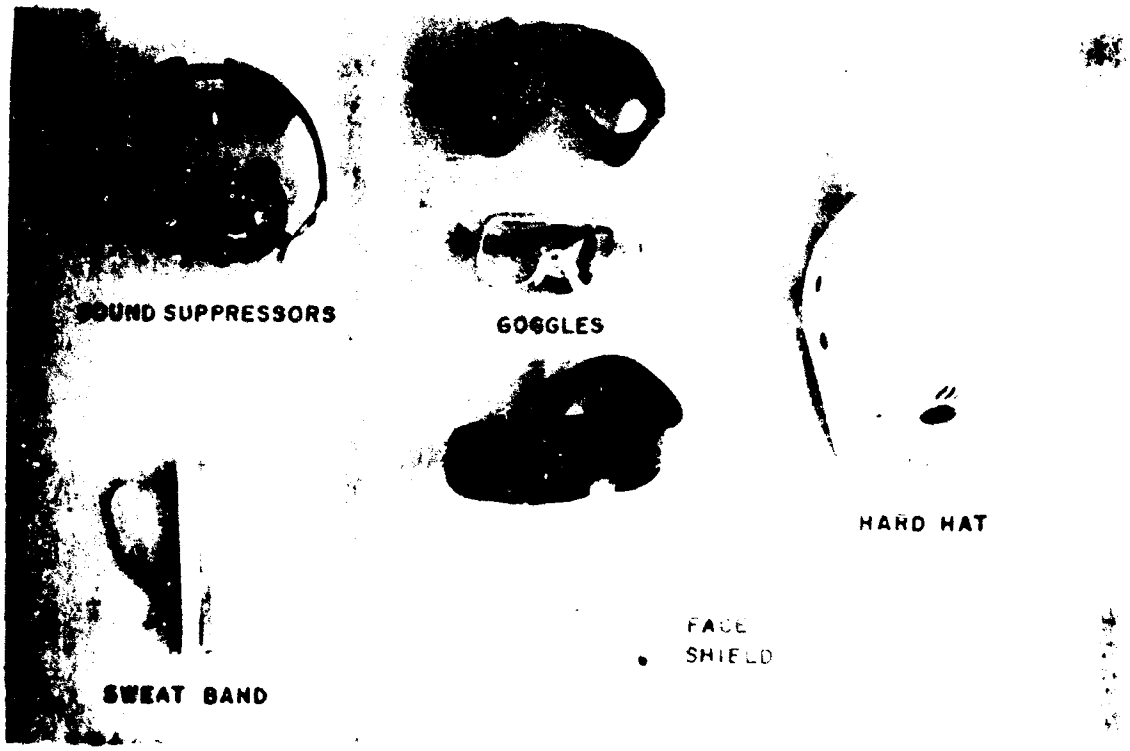
F. Face Shields

Approved plastic face shields shall be worn by personnel exposed to flying sparks, shavings, splashing of hazardous liquids, etc. (see Figure 1-6). Face shields shall be kept away from excessive heat and strong solvents that will soften and discolor the shields.

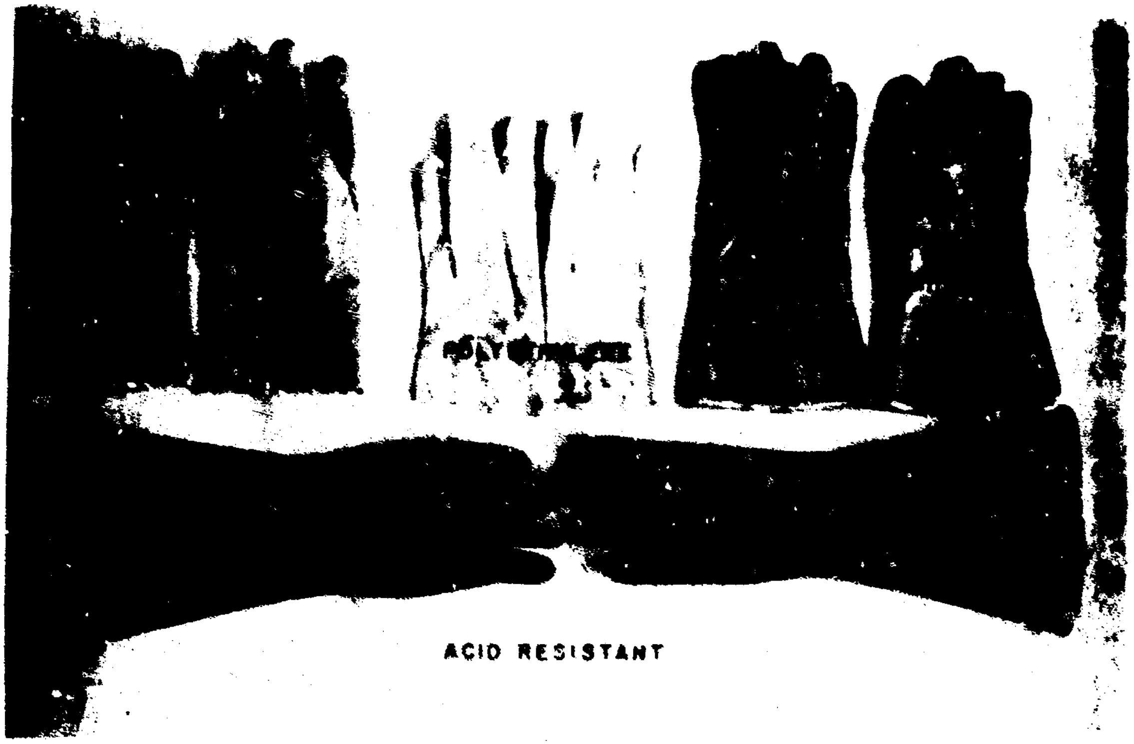
G. Hard Hats

Approved hard hats shall be worn by personnel when engaged in missile launching pad operations. They shall also be worn in any other operation that could possibly cause injury to the head (see Figure 1-6).

H. Gloves




HEAD, FACE, EYE AND EAR [illegible]




GLOVES

[illegible]

Gloves of the proper type shall be provided to personnel exposed to hazardous materials. The types of gloves utilized by employees in the Solid Propellants Area are shown in Figure 1-6.

I. Respiratory-Protective Equipment

1. Design Requirements

Only respiratory-protective devices approved by the Bureau of Mines and acceptable under the U. S. Air Force regulations shall be used.

2. Type

In general, all respiratory-protective equipment can be classified in three (3) major groups:

a. Equipment that purifies the inhaled air and makes it breathable.

b. Equipment that requires an air or oxygen supply from an outside source.

c. Self-contained breathing apparatus that provides its own air or oxygen.

All three (3) of these basic classes of equipment include a variety of devices, each designed to serve best under certain conditions. The fundamental characteristics of these devices are summarized as follows:

(1) Air Purifying Equipment

This equipment is suitable for use in atmospheres that contain sufficient oxygen to support life and from which the contaminants can be removed or rendered harmless by mechanical or chemical filters. Included in this class of equipment are mechanical-filter respirators, chemical-cartridge respirators and canister-type gas masks.

(2) Supplied Air Equipment

(a) Air-Line Respirators

The air-line respirator is used mostly in unconfined spaces for protection against paint-spray vapors, welding fumes, etc.

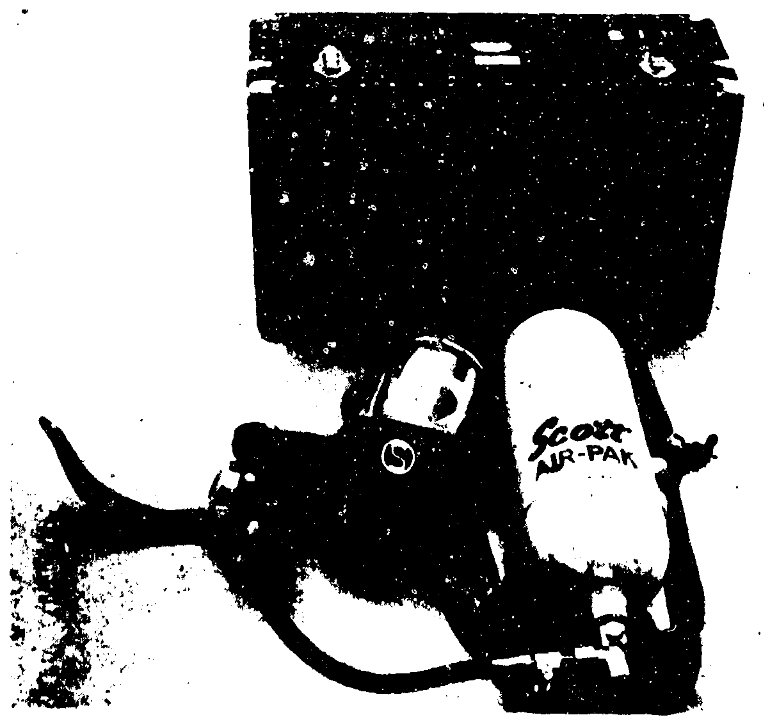
(b) Hose masks obtain air from an

uncontaminated source and may be used in a highly contaminated or oxygen deficient area.

(3) Self-Contained Breathing Apparatus

A self-contained breathing apparatus operates independently of the surrounding atmosphere. It includes an air or oxygen supply in a cylinder or a method of generating oxygen. Equipment of this type provides complete respiratory protection in any concentration of toxic gases and under any condition of oxygen deficiency (see Figure 1-7).

MSA OXYGEN RESPIRATOR




SCOTT AIR - PAK

FIG. I-7: SELF-CONTAINED BREATHING APPARATUS

## IV. PACKING AND MARKING OF EXPLOSIVES AND AMMUNITION

### A. General

The wide range in the sensitivity, stability and hygroscopicity of explosives and propellants has resulted in the development of varied types of packing. The sensitivity of initiating explosives to shock and friction and black powder to spark and flame necessitates special packing techniques. The effects of moisture on the stability of some propellants and the hygroscopicity of many propellants also require special packing precautions. Some of these special packing requirements include the packing of explosives in a wet condition and the use of airtight-containers that must withstand a prescribed internal pressure. The non-hygroscopicity and relative insensitivity of some high explosives permits the use of collapsible cartons. These cartons may be reused when similar explosives are packed for interplant shipment or short-term storage.

Bulk priming, pyrotechnic, smoke, tracer and incendiary compositions are not subjected to shipment or storage, since they are loaded at the plant where they are manufactured. Special packing containers, therefore, are not prescribed for these compositions.

The markings of containers for explosives and propellants are prescribed by the general specifications and drawings issued by the Air Force, Army and Navy. These also comply with regulations of the Interstate Commerce Commission. The most generally used markings include: the name of the material, lot number, specification number, manufacturer's initials or symbol, ammunition identification code symbol, contract number, date of manufacture, gross weight, cubical displacement and the dangerous commodity designation required by the Interstate Commerce Commission regulations. Markings may also include the grade and/or class of explosives, the plant where they are manufactured and the box number. Initiating explosives are marked to indicate their nature and compatibility of storing or loading with other explosives.

### B. Initiating Explosives

The sensitivity of initiating explosives to shock and friction necessitates that packing be accomplished while in a wet condition. Due to the low solubility of lead azide, mercury fulminate, diazodinitrophenol and lead styphnate, water may be used as the wetting agent. However, if shipment or storage under low-temperature conditions is anticipated, a mixture of equal weights of water and ethanol is permitted.

Approximately twenty-five (25) pounds of the explosive, wet with not less than twenty (20) per cent of liquid, is placed in a duct or rubberized-cloth bag and covered with a cap of the same material. The bag is tied securely to prevent leakage. Not more than six (6) bags are placed in a larger bag of the same material. The larger bag is tied securely and placed in the center of a watertight-metal or wooden barrel, drum or keg that is lined with a heavy, close-fitting, jute bag. The large bag containing the explosive is surrounded with tightly-packed sawdust that has been saturated with water or a water-ethanol mixture. The jute bag is sealed by sewing before the barrel, drum or keg is closed. Not more than 150 pounds (dry weight) of initiating explosive is permitted in a single container.

C. Non-Initiating High Explosives

Nitroglycerin, uncombined with other materials, shall not be shipped by commercial means. Nitroglycerin should only be used in the place where it is manufactured.

Due to its sensitivity to spark, nitrocellulose shall be shipped only when wet. It shall contain at least twenty (20) per cent water by weight and be packed in watertight drums.

Due to their sensitivity to shock, RDX and PETN must be wet with water or an ethanol-water mixture. The resulting slurry shall contain not less than forty (40) per cent liquid by weight. This slurry is placed in duct, rubber or rubberized cloth bags which hold not more than fifty (50) pounds (dry weight) of explosive. These bags of explosives are placed in a larger bag of the same material. The small bags are surrounded with water and the large bag is closed securely. The bag is then placed in a watertight barrel, keg or drum. The dry weight of explosive in one (1) container must not exceed 300 pounds. During World War II, the Germans packed RDX in a dry condition.

Ammonium nitrate, because of its great hygroscopicity, is packed in moistureproof-metal drums or paper bags. The metal drums are lined with paper and may be of the single-trip type. Single-trip drums and burlap-covered paper bags used for packing ammonium nitrate have a maximum capacity of one hundred (100) pounds.

TNT, tetryl, explosive "D", picric acid, haleite and nitroguanidine are almost non-hygroscopic. For lengthy storage or overseas shipment these explosives are packed in wooden boxes lined with waterproof-paper

that hold 50 to 100 pounds of explosive (see Figure 1-8). For interplant shipment or temporary storage these explosives may be packed in fiber cartons that are lined with a waterproof-paper bag that holds approximately fifty (50) pounds of explosives (see Figure 1-9). These cartons are collapsible and may be reused. The paper-bag liner is destroyed after the contents are removed.

The binary explosives: amatol, tetrytol, picratol, torpex and tritonal are generally manufactured at the loading plants where they are to be used and are not subjected to packing. Pentolite, composition A-3 and composition B are sometimes shipped to loading plants or placed in storage. They are packed in a dry condition in fifty (50) pound capacity wooden boxes or fiber drums lined with moisture-proof-paper bags. They can be packed in a dry condition since they are much less sensitive than the PETN and RDX from which they are made. Composition C-3, when shipped in bulk, is packed in wooden boxes that are lined with oilproof and moistureproof-paper bags. The capacity of these boxes is fifty-eight (58) pounds.

Military dynamites and demolition explosives, for example the C-3 composition, are packaged in one (1) pound sticks or blocks. These explosives are wrapped in oilproof and moistureproof-paper and are packed in paper-lined wooden boxes containing fifty (50) pounds of explosives.

D. Black Powder

Due to its extreme sensitivity to spark and its great hygroscopicity, black powder is packed in airtight-steel drums that contain twenty-five (25) pounds of powder.

E. Propellants

Propellants are packed in airtight-containers. The hygroscopicity of nitrocellulose propellants and the adverse effect of moisture absorption on stability and ballistic value necessitates this special packing requirement. Copper-lined wooden boxes, tested for resistance to air pressure of five (5) psi, were formerly used for all types of propellants and are currently standard (see Figure 1-10). These boxes vary in size, the largest holding approximately 150 pounds of propellant. More recently standardized containers of stainless steel with a bonded outer layer of plywood and containers made of heavier, galvanized steel have been used (see Figure 1-11). Containers for propellants have relatively large, rubber-gasketed closures of the clamping type with pressure applied by means of a screw. It is known that pro-

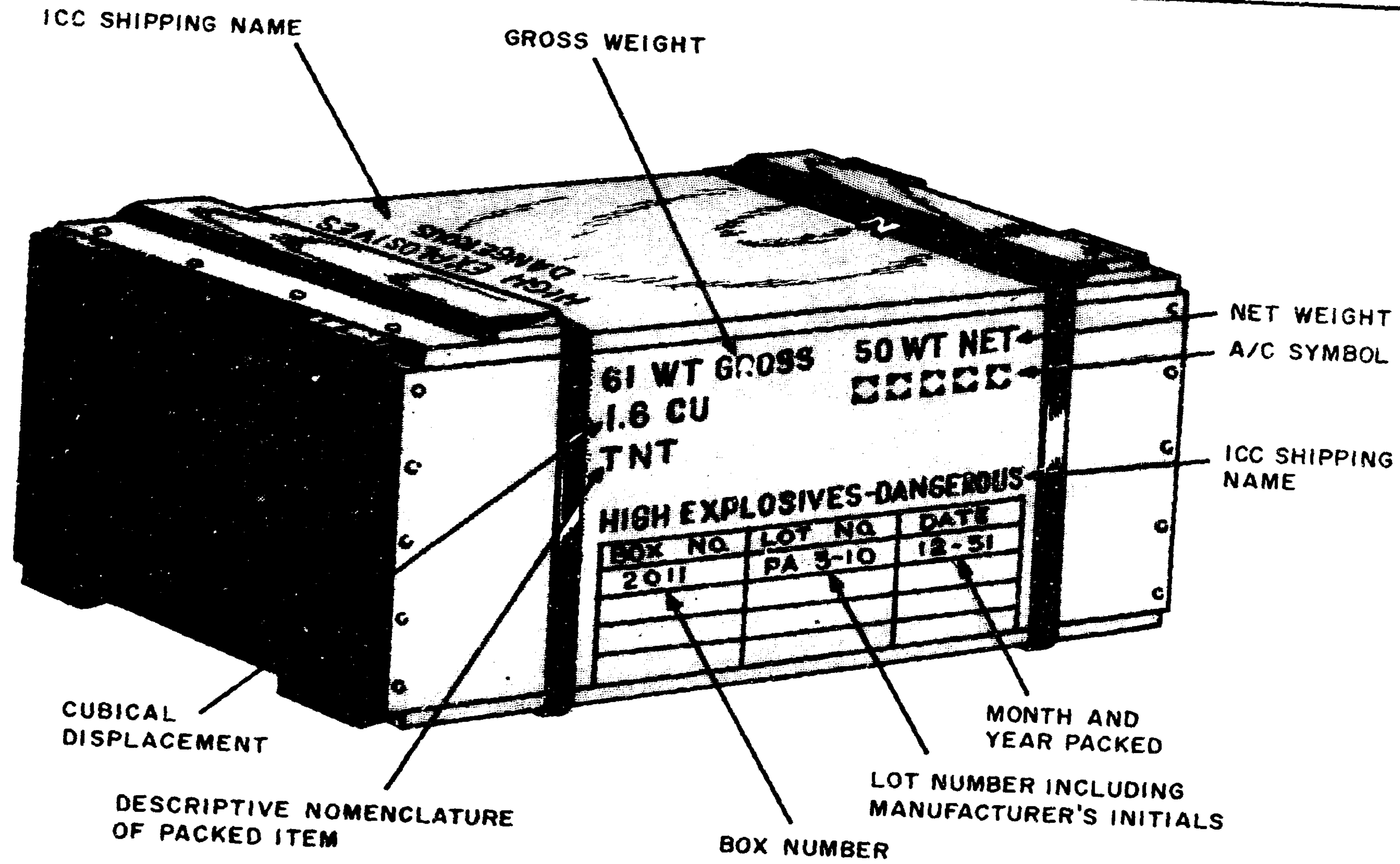



FIG.1-8: WOODEN BOX FOR PACKING HIGH EXPLOSIVES

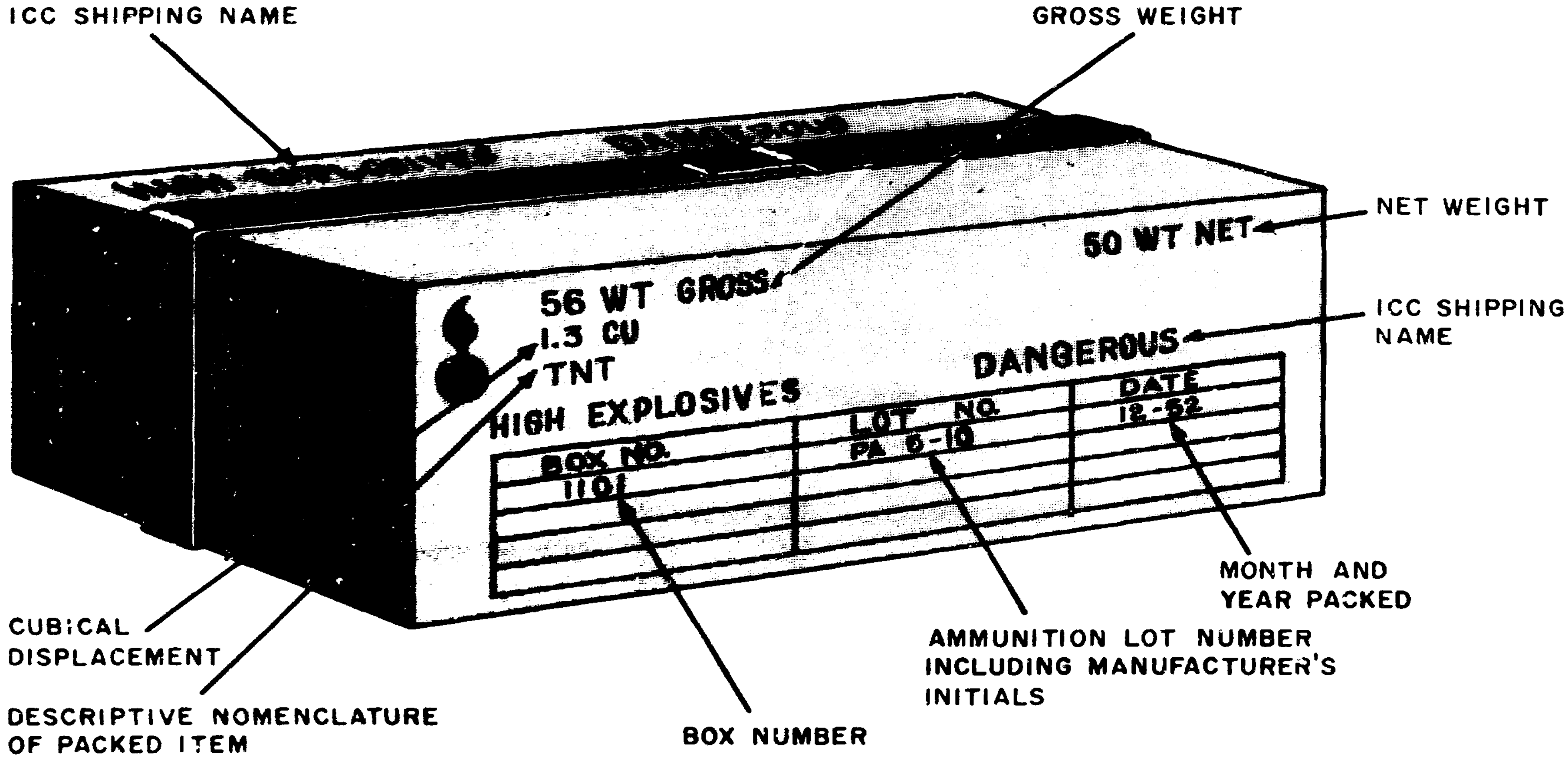



FIG. I-9: FIBER CARTON FOR PACKING HIGH EXPLOSIVES

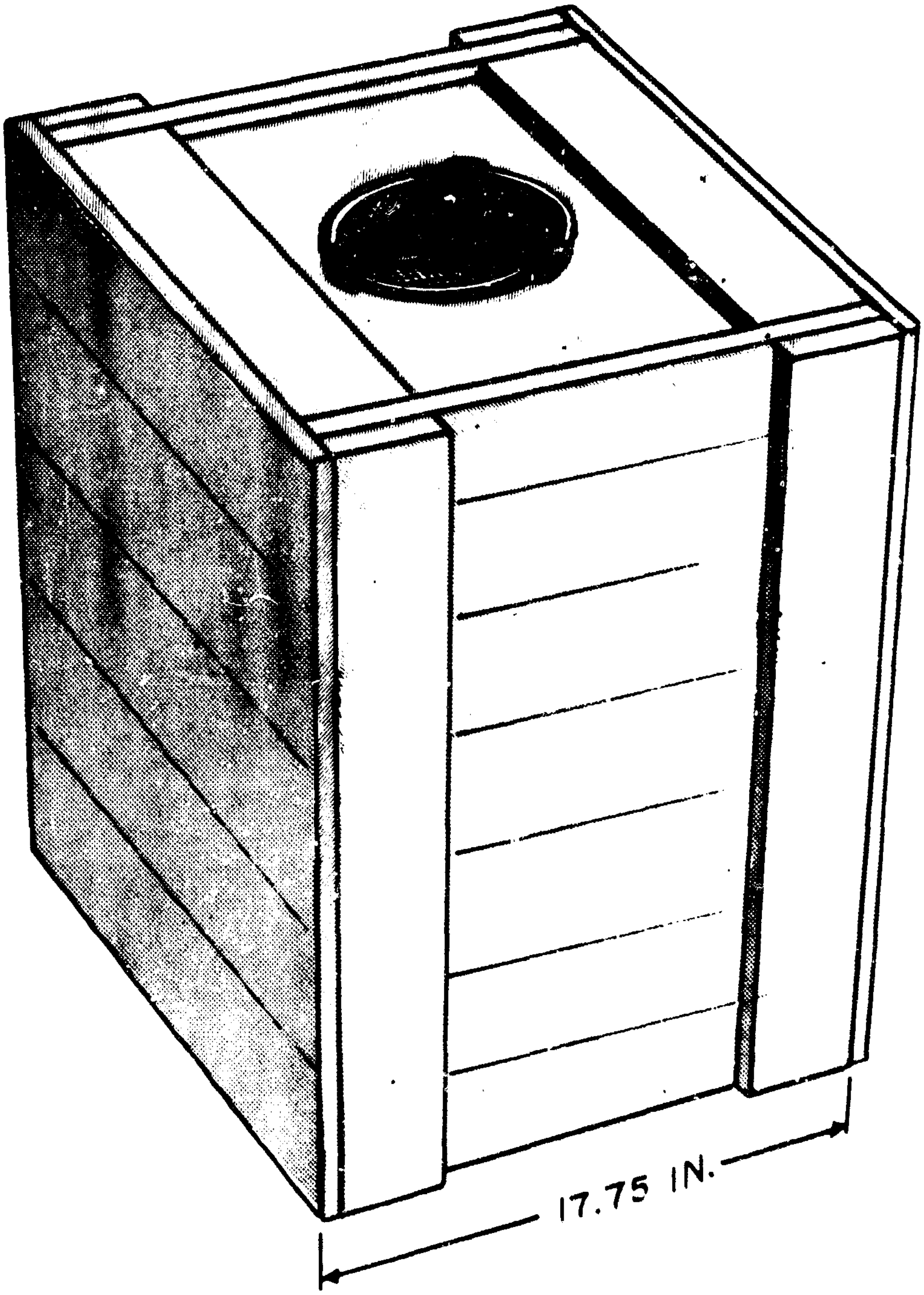



FIG. 1-10: WOODEN BOX FOR PACKING PROPELLANTS

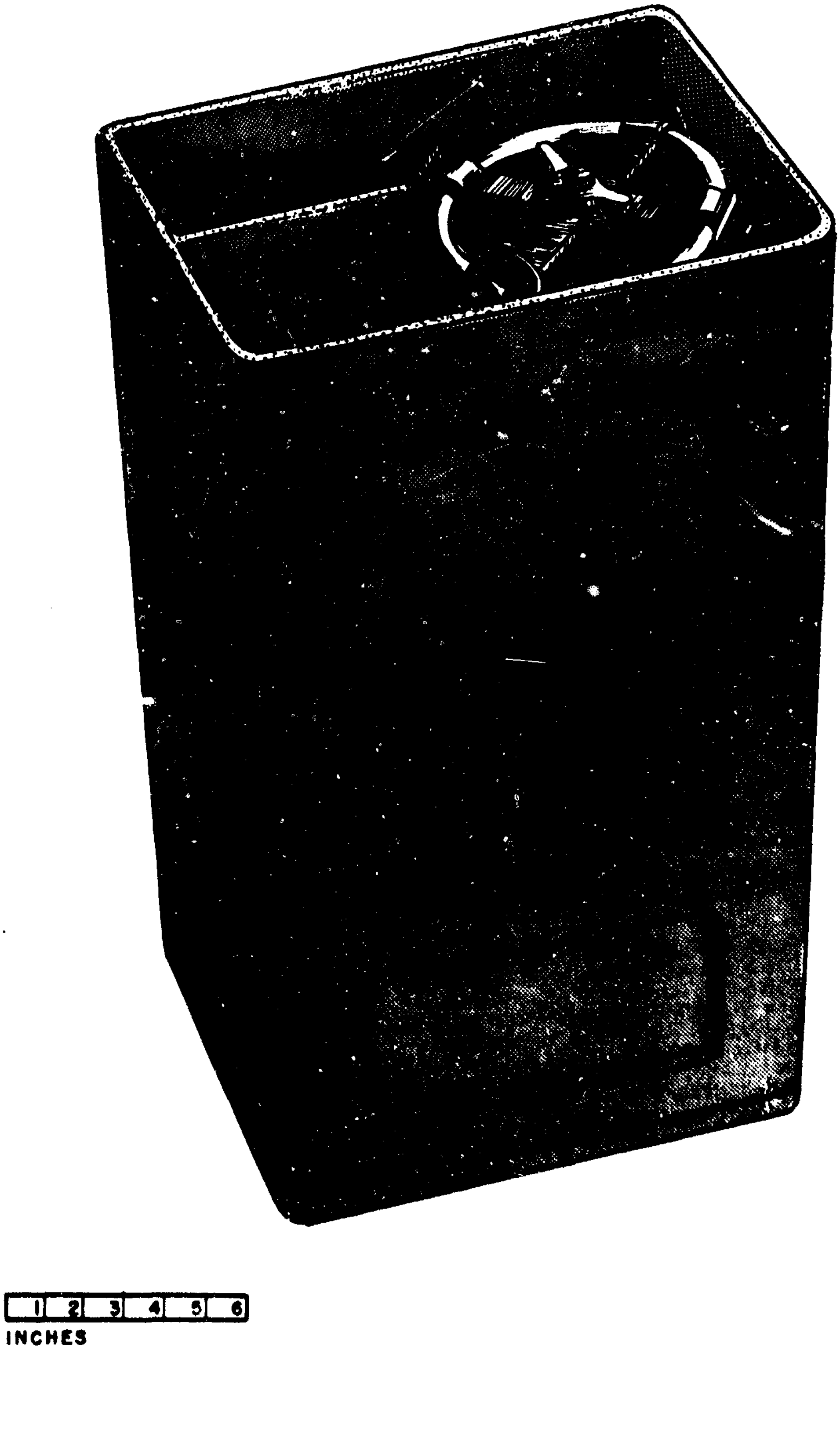



FIG. 1-11: STEEL BOX FOR PACKING PROPELLANTS

pellants stored in these containers do not undergo changes in moisture content even when subjected to the adverse conditions of tropical storage.

F. JATOS

Small JATOS are generally shipped completely assembled. Large JATOS are usually shipped with igniters packed separately. Certain igniter assemblies and propelling charges (refills) are also shipped separately. The JATO, dependent upon size and weight, may either be packed for shipment in a wooden box, wooden crate or on a pallet. The specific packing required for each JATO and its separately issued components is described in a technical manual for the specific JATO. Complete packing and shipping data is published in the Department of the Army's Supply Manual ORD 3 SNL S-9.

G. Components of Guided Missiles

The components of guided missiles are packed in appropriate types of containers. Fuzes and warheads are packed in wooden or metal containers. Propellants, solid or liquid, are packed in specially designed tanks, metal drums, glass bottles or fiber containers in wooden boxes. Control and guidance equipment are packed in specially constructed containers since they are precision instruments. Propulsion systems are packed in metal crates or wooden boxes. Compressors, cable sets, storage batteries, firing panels and similar items of special equipment are also packed in suitable boxes, crates and containers.

## V. TRANSPORTATION OF EXPLOSIVES AND AMMUNITION

### A. General

Railroads, ships, barges, aircraft and commercial and military trucks are the chief means utilized for the transportation of explosives and ammunition. With the exception of laboratory samples, all railroad shipments are accomplished via freight. It is permissible to ship laboratory samples by express. The shipment of explosives and ammunition must be made with the utmost care because of shocks during transportation, increased handling and the hazards associated with changing environment. Problems regarding the safe shipment of explosives and ammunition are similar to those of storage; therefore, special regulations have been developed to insure maximum safety when shipping these items.

During World War II, some accidents involving explosives and ammunition resulted from handling during loading and unloading operations incident to transportation. However, any explosion that occurred during actual transportation in the United States was caused by fire that originated somewhere other than in the explosive material. In view of the enormous tonnages of these materials transported, this record is testimony to the effectiveness of the regulations for packing and shipping explosives and propellants.

### B. Regulations

Published regulations pertaining to the transportation of explosives are listed below:

1. Interstate Commerce Commission Regulations, Transportation of Explosives and Other Dangerous Articles by Freight
2. Interstate Commerce Commission, Motor Carrier Safety Regulations, Part Nos. 1 to 7 inclusive
3. Departments of the Army, Navy and Air Force Regulations and Instructions
4. Bureau of Explosives' Pamphlets No. 6 and No. 6A
5. U. S. Coast Guard, Regulations Governing Transportation of Military Explosives on Board Vessels and Regulations for the Security of Vessels in Port
6. U. S. Department of Commerce, Bureau of

Marine Inspection and Navigation's Regulations Governing Transportation, etcetera, of Explosives

7. U. S. Civil Aeronautics Board, Civil Air Regulations, Part 49, Transportation of Explosives and Other Dangerous Articles

8. Freight Tariff No. 10

9. State and municipal laws and port and harbor regulations where applicable.

The above regulations cover the inspection of freight cars, boats, aircraft and motor vehicles prior to loading with explosive materials. They also cover the loading and staying of shipments, the placarding of cars and trucks, the labeling of packages to indicate the nature of shipments, the placement of freight cars in trains, the inspection of shipments prior to unloading and the quantities of items permitted in individual cars, aircraft, barges and trucks.

C. Freight Shipments

Freight Tariff No. 10, publishing I.C.C. Regulations for the Transportation of Explosives and other Dangerous Articles by Freight, establishes thirteen (13) classes of hazardous materials. Three (3) of these classes comprise explosives, propellants, assemblies and ammunition. Some of the military explosives included in these three (3) classes are as follows:

1. Explosives, Class A:

| | |
|---|---|
| Lead azide | Picric acid |
| Mercury fulminate | Explosive "D" |
| Lead styphnate | RDX |
| Diazodinitrophenol | Nitroguanidine |
| High explosives or propellant explosives | Haleite |
| Black powder | Dynamite |
| Low explosives | Nitrostarch |
| TNT | JATO units |
| Tetryl | Igniters |
| PETN | Rocket motors |

2. Explosives, Class B:

| | |
|---|---|
| Smokeless powder | Fireworks |
| JATOS | Igniters |

3. Explosives, Class C:

| | |
|---|---|
| Blasting caps (1,000 or less) | Time-blasting fuse (safety fuse) |

| | |
|---|---|
| Primers | Electric squibs |
| Cordeau detonant | Delay-electric igniters |

It may appear that Class A explosives include an unduly wide range of materials from the viewpoint of sensitivity. However, when these explosives are packed as described under the subsection entitled "Packing and Marking of Explosives and Ammunition," which is included in this Section of the MANUAL, the factor of sensitivity may be considered fairly constant for all materials in this class. Class A explosives, therefore, are those substances that represent an explosion hazard in case of fire but not in case of an accident without fire. Accident statistics involving transportation substantiate this generalization. The transportation of liquid nitroglycerin, as such, by freight is not permitted and it is not included in Class A explosives.

Class B explosives include materials which are principally a fire hazard. Wet nitrocellulose, which may be expected to be included in Class B, is included in the class of flammable solids. The transportation of dry nitrocellulose via freight is not permitted. Ammonium nitrate, although it has some explosive characteristics under extreme conditions, is not included in Class B but in the class of dangerous articles comprising oxidizing materials.

Class C explosives contain items or devices that include Class A or Class B explosives as components in small quantities. These assemblies represent an explosion hazard in case of fire. Class C explosives could initiate the explosion of any adjacent materials in Classes A and B.

The establishment of these three (3) classes provides for the proper separation of these and other dangerous articles during transportation via railway freight. The extent of damage in the case of accident or sabotage may be minimized by proper packing and separation of these materials. The Bureau of Explosives of the Association of American Railroads is an official advisory body on explosives. Its functions are to perform tests on explosives and offer recommendations to the Interstate Commerce Commission on which regulations for the freight transportation of explosives are based.

D. Motor Shipments

1. The Motor Carrier Safety Regulations of the Interstate Commerce Commission establish three (3) classes of explosives that cor-

respond closely with those established for railway freight shipments. These are described as follows:

a. Dangerous explosives, Class A, include:

(1) High explosives that can be detonated by a blasting cap, including dry nitrocellulose, dry nitrostarch and fireworks that can explode en masse

(2) Black powder and low explosives

(3) Blasting caps and electric-blasting caps

Items of this class may be shipped in a common motor carrier that consists of a truck without a trailer. They may also be shipped by a semi-trailer attached to a tractor, however, no other form of trailer may be attached to this vehicle. Liquid nitroglycerin is not included in this class.

b. Less dangerous explosives, Class B, include smokeless powders for cannon and small-arms and fireworks not subject to explosion en masse.

c. Relatively safe explosives, Class C, include squibs, primers, cordeau detonant, etcetera.

2. Ammonium nitrate is not classified as an explosive relative to motor transportation but as an oxidizing material. Separate regulations apply to the transportation of oxidizing materials.

E. Boat Shipments

Boat shipments are controlled by Coast Guard Regulations as found in the Code of Federal Regulations, Title 46. Coast Guard Regulations establish Classifications of Class A, dangerous explosives, Class B, less dangerous explosives and Class C, relatively safe explosives. This division into classes corresponds to those established by I.C.C. Regulations for Motor Transportation.

F. Aircraft Shipments

Civil Air Regulations permit limited shipments of

explosives and propellants by aircraft. The packaging, labeling and classification of these materials are in accordance with I.C.C. regulations for freight and express shipments.

Passenger aircraft are not permitted to transport Class A or Class B explosives except picric acid, explosive "D" and TNT. These explosives must be shipped as medical or chemical materials. They shall contain at least ten (10) per cent water by weight and be shipped in outside containers having maximum contents of sixteen (16) ounces. Class C explosives, except blasting caps, may be carried on passenger aircraft. Individual outside containers of Class C explosives shall not contain more than fifty (50) pounds. Cargo aircraft may transport explosives permitted in passenger aircraft. They may also transport explosives other than blasting caps that are packed, labeled and otherwise acceptable for express shipment in accordance with I.C.C. Regulations.

## VI. STORAGE OF EXPLOSIVES AND AMMUNITION

### A. General

Explosives and ammunition are stored, preferably, in earth-covered, concrete magazines called igloos (see Figure 1-12). Prior to storage these items are packed in standard containers which include wooden boxes, steel drums, metal crates, cartons, etcetera. For further information concerning containers for explosives and ammunition see the subsection entitled "Packing and Marking of Explosives and Ammunition" which is included in this Section of the MANUAL.

Magazines shall be located in areas provided with an approved drainage system to prevent moisture deterioration to items stored therein. Grass or other vegetation adjacent to and extending over igloo magazines must be mowed at frequent intervals and all dry debris must be removed. A fifty (50) foot area surrounding the igloos shall be maintained free from rubbish, dry grass or other material of a combustible nature. Trees may remain in magazine areas, provided they are separated from adjacent woods or forests by fire lanes or open areas.

### B. Magazine Construction

#### 1. General

The magazines used for the storage of explosives, ammunition and solid propellants at CCMTA are of the reinforced concrete, earth-covered, igloo type with a barricaded door end. The present magazines were constructed in accordance with the Corps of Engineers' Ordnance Drawings.

Magazines or igloos are specifically designed for the type of explosives, ammunition and solid propellants to be stored. Magazines used for storing pyrotechnic materials are similar to those used for storing primer fuses and detonators. The magazines used to store boosters, rockets, JATOS and high explosives are much larger and are shaped differently than the pyrotechnic igloos.

#### 2. Shape

Pyrotechnic igloos are square or oblong on the inside. They vary in length and width but are usually only ten (10) feet high.

FIG. 1-12: EXPLOSIVES, AMMUNITION AND SOLID PROPELLANTS STORAGE AREA

Magazines housing boosters, rockets, JATOS or high explosives are the elongated, arched-roof type. They vary in length, width and height.

Magazines or igloos are constructed of steel reinforced concrete two (2) feet thick at the side base and tapering to approximately fifteen (15) inches at the breaking point where the arched-roof begins. The arched-roof tapers to approximately eight (8) inches thick at the crown.

3. Barricade

Earth-covered, above-ground magazines are covered with approximately 2 to 3 feet of earth and are sloped at a 2 to 1 pitch.

The barricade at the door-end of the magazine access road is constructed of steel reinforced concrete (see Figure 1-13). The barricade is two (2) feet thick at the base and tapers to eighteen (18) inches at the top. It extends to an altitude higher than the steel doors and is as wide as the front end of the igloo. This concrete wall is backed by an earth-mound on a 2 to 1 slope.

The earth covering is seeded and the grass is cut short and maintained in this manner for a distance of at least fifty (50) feet from the bottom of the slope.

4. Floor

The floor is steel reinforced, spark-proof concrete. It is high pointed at the center to give a one (1) inch slope into lengthwise drains located on both sides of the magazine. The drains are 2 or 3 inches deep.

5. Lighting

The lighting system contains one, two or four explosion-proof spot lights located on the door-end barricade which are mounted to direct light into the magazine (see Figure 1-13).

6. Grounding System

The grounding system is a #1/0 copper cable hooked to end-rings attached to the reinforced steel of the magazine. These end-rings are located on the outside of the magazine on both sides at the top and bottom. They are connected by a #1/0 copper ground conductor that encircles the igloo. This

MAGAZINE - AIR CONDITIONED


MAGAZINE - PYROTECHNIC AND ORDNANCE ITEMS

FIG. 1-13: IGLOO-TYPE MAGAZINE - STORAGE OF SOLID PROPELLANTS

ground conductor is placed approximately eighteen (18) inches below the existing grade of earth-fill and ground level.

7. Lightning Protective System

Lightning rods are provided at the front and rear of the igloos. They extend two (2) to four (4) feet above the highest point of the earth-fill and are attached by cable to the grounding system (see Figure 1-13).

8. Ventilation System

Some magazines are air-conditioned or heat-conditioned, others are equipped with a fresh air vent that connects the internal area of the magazines to the outside by a duct. The air vent rises approximately one and one-half to two feet above the earth-fill of the igloo (see Figure 1-13). A screen installed in the duct prevents rodents, small animals and pests from entering the igloo.

9. Doors

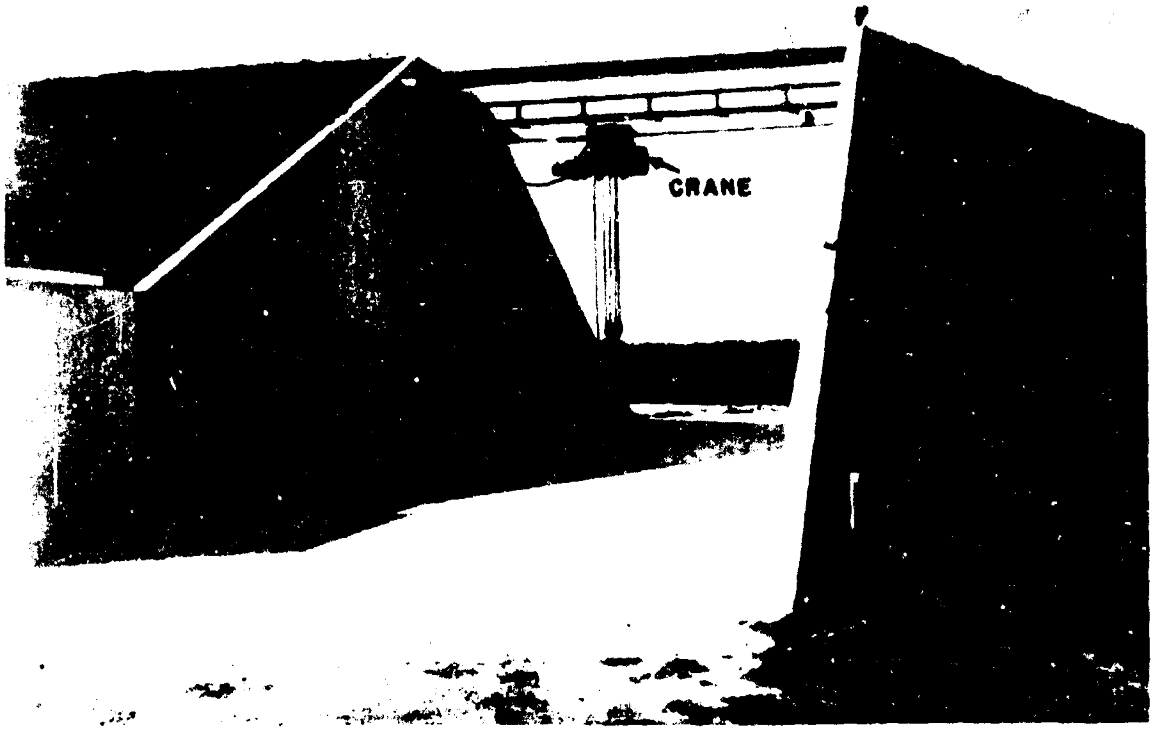
Magazine doors are constructed of 5/8" armor-plate steel on the outside and 1/4" steel plate inside (see Figure 1-13). They are insulated internally with asbestos batting. The dual doors are approximately three (3) inches thick, tri-hinged and are provided with an overlapping at the closure face to insure tightness. The doors are also provided with a welded hasp for locking purposes. In some of the large magazines the dual doors are on rails so that they can be opened by sliding.

10. Crane System

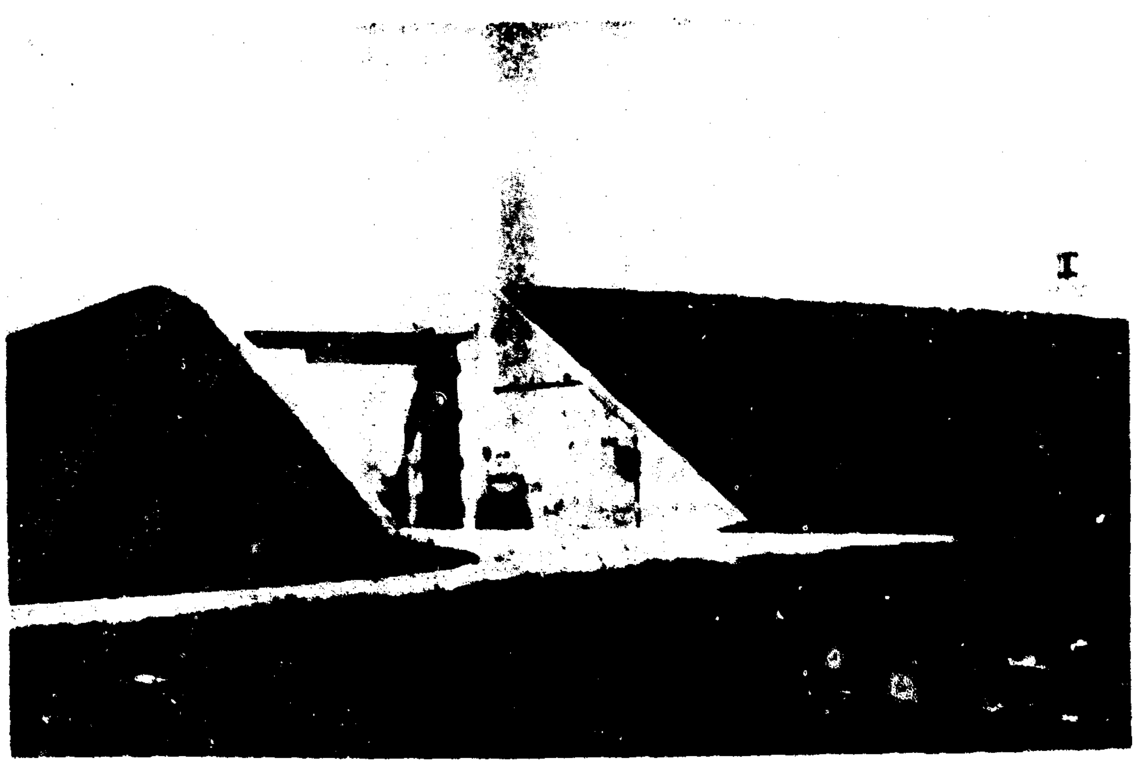
Most of the magazines are provided with over-head, chain-operated cranes (see Figure 1-14). These are attached to an I-beam that is anchored at the rear of the magazine and to the door-end barricade. The I-beam of the crane rail extends the length of the igloo to the outside.

11. Access Road

A hard-surfaced asphalt road provides access to the magazines. The width of the access road is twenty (20) feet for small magazines and thirty (30) feet for large magazines. The road forms a half circle between the front-end barricade and the igloo. Access is gained from either side of the area road.




LARGE SOLID PROPELLANT ROCKET STORAGE



SMALL SOLID PROPELLANT ROCKET STORAGE

FIG. I 14 IGLOO-TYPE MAGAZINE - STORAGE OF SOLID PROPELLANT ROCKETS

12. Fire Symbols or Hazard Markers

a. General

Each magazine is provided with a sign on either side of the magazine entry way. The signs provide a guide to indicate the relative danger to be encountered by the fire-fighting crews when actively engaged in fighting a fire in the explosives and ammunition magazine area. Buildings and storage sites containing hazardous or explosive materials must be plainly marked with the pertinent fire-hazard symbol (see Figure 1-13). The symbol used shall apply to the most hazardous material contained within the building or magazine. To facilitate recognition, distinctive background shapes have been developed for each symbol:

(1) Symbol 1 - rectangular-shaped background

(2) Symbol 2 - square-shaped background

(3) Symbol 3 - diamond-shaped background

(4) Symbol 4 - octagonal-shaped background

(5) Chemical Ammunition - circular-shaped background without explosive components

The symbol background used should be twenty-four (24) inches high and twenty (20) inches wide. The background should be international orange or yellow. The symbol numbers should be black.

b. Chemical Ammunition Symbols

The same fire symbols shall also be used to identify chemical ammunition storage facilities for fire-fighting purposes. The type or types of fire symbols will depend not only upon the type of chemical agent in the ammunition but also upon the absence or presence of explosive components in the ammunition.

Storage facilities for chemical ammunition containing no explosive components shall be marked with fire symbols described as follows:

(1) A circular sign twenty-four (24) inches in diameter with an international orange or yellow background.

(2) Persistent poisonous gases shall be indicated by two (2) green stripes four (4) inches wide and four (4) inches apart. These stripes shall be painted diagonally on the circular sign indicated in Par. (1) and shall extend from upper right to lower left.

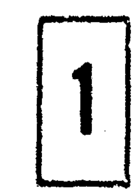
(3) Non-persistent poisonous gases shall be indicated by a single, green, four (4) inch stripe on the circular sign. This stripe shall be centered diagonally on the sign and it shall extend from upper right to lower left.

(4) Incendiaries and other materials which are not easily extinguished by water shall be indicated by the letter "D". The letter "D" is painted in black on the international yellow or orange background.

Storage facilities for chemical ammunition containing explosive components shall be designated by explosive fire symbols with the appropriate chemical ammunition symbol superimposed on them. This arrangement will denote the combined explosive component and chemical agent hazard.

c. Description of Fire-Hazard Symbols

Symbol 1




This group consists of explosives and ammunition in quantity-distance Classes 1, 11 and 12 and fuels and oxidizers in classes 150 and 1050 when used together as propellants. It also includes solvents, oils, paints, compressed gases and other inorganic oxidizing agents in sealed containers. These materials are principally fire hazards but minor explosions may be expected. Fires involving these materials must be fought with mobile fire extinguishing equipment until the fire has been completely extinguished. A mobile first aid unit must stand by to treat possible injuries resulting from the fire.

Symbol 2


Explosives and ammunition under this symbol present limited explosion hazards. Personnel discovering a fire in this type material shall first sound the fire alarm and then attempt to extinguish the fire with the equipment on hand if the fire is at the incipient stage. When the mobile-fire equipment arrives the fire should be extinguished only when indications are that the fire can be extinguished without limited explosions. When the possibility of an explosion is indicated the area should be cleared and the Fire Department prepared to combat small spreading fires resulting from the explosion and burning debris.

Materials stored under the Symbol 2 include Class 3 explosives and ammunition. These materials include fuses without boosters, practice grenades, spotting charges, JATO-electric igniters, artillery and cannon primers and primer detonators.

Symbol 3


Personnel in the immediate vicinity of a Symbol 3 fire shall activate deluge systems and sound the alarm, but they shall not expose themselves to undue hazards. The Fire Department shall confine its operation in preventing the spread of fire to other buildings, unless the fire is of a minor nature and does not involve the explosive itself. Fire involving these materials produces intense radiant heat over a wide area, which is dangerous to personnel and equipment in the vicinity. Extreme caution shall be observed by personnel of the Fire Department when combating this type of fire.

Symbol 3 materials consist of quantity-distance Class 2 and 2A propellants, Group C and D chemical ammunition (not assembled with explosive components) and Class 2 pyrotechnic materials.

Symbol 4


No attempt shall be made to fight fires involving Symbol 4 material except for manual activation of installed automatic fire extinguishing equipment. These materials may be expected to detonate when involved in a fire, and except for explosives and ammunition of Classes 4 and 5 are subject to mass detonation. Personnel shall leave the building immediately when the fire begins. They shall protect themselves as much as possible and activate deluge systems and fire alarm equipment while escaping. When a fire in a Symbol 4 building is small and involves non-explosive materials, an attempt may be made to extinguish it with an extinguisher or other readily available means.

When the Fire Department arrives, supervision shall advise them of the nature of the fire and the kind of material involved or likely to be involved. When Symbol 4 materials are directly implicated, fire-fighting forces shall observe strict quantity-distances (see Air Force and Army Quantity-Distance Classification of Explosives and Ammunition, pages 1-6 through 1-25). They shall maintain a distance of 1000 feet from fires in which the quantity of explosives involved is 50,000 pounds or less, and proportionately greater distances up to 2000 feet when 100,000 pounds of explosives are involved. Mobile equipment shall be kept at a protected location.

When the Fire Chief and Area Supervisor concur on the procedure, fire-fighting forces may advance to extinguish the fire or protect adjacent buildings. Such action is never undertaken until the possibility of an explosion has been eliminated. Under no circumstances shall a person enter a Symbol 4 building in which there is a fire.

The safety of personnel in fighting a Symbol 4 fire depends on the accuracy of the information made available to the fire-fighting forces. No effort shall be made to fight the fire when the safety of personnel is in doubt. Personnel and equipment shall seek shelter and remain at a safe distance from the building. Fires in igloo-type magazines shall be fought

only when the contents are determined to be a fire hazard.

Symbol 4 materials include quantity-distance Classes 4 through 10 explosives and ammunition, and Class 950 liquid fuels and oxidizers used as propellants.

C. Magazine Storage

Containers of explosives and ammunition are stored in magazines in accordance with special instructions. In general, the containers are stored separately or in stacks with aisles provided between stacks and magazine walls. Storing explosives in this manner facilitates inspection and removal of the individual units. Methods of stacking must also provide ample ventilation to all parts of each stack.

Partially filled boxes of explosives must be marked conspicuously and stored apart from full boxes. Damaged containers of explosives must not be stored in a magazine with serviceable containers. Open containers and containers with insecurely fastened covers are not permitted in storage magazines. No repair work will be undertaken in magazines storing explosives. See "Air Force and Army Group Summary of Storage Compatibility for Explosives and Ammunition," pages 1-33 through 1-40 for specific storage requirements.

D. Inspection of Magazines and Magazine Areas

1. General Inspection Requirements

Magazines and magazine areas shall be inspected once a week or more frequently as directed by local regulations. These inspections are necessary to assure that normal humidity and temperature are maintained within the magazine and that all containers are in satisfactory condition. A check should be made during magazine inspections to ascertain that the following conditions prevail:

a. The magazine area is adequately protected against fire.

b. Firebreaks are kept clean of rubbish and flammable material.

c. Magazines are properly maintained to insure that they remain dry, adequately ventilated and in a general satisfactory condition.

d. The interiors of magazines are clean and

neat with stores orderly arranged.

e. Compliance with the requirements of the Air Force and Army Storage Compatability Groups (see pages 1-33 through 1-40) are being enforced.

f. The stores are properly identified by lot number and stacked so that there is no more than one (1) lot in each stack.

g. Loose rounds, damaged containers, empty containers, paint, oil, waste, rags, tools and other prohibited articles are not present in the magazine.

h. All ammunition and explosives are in segregated magazines and not in buildings used for other purposes.

i. Records and publications are not kept in magazines.

j. In the event a magazine contains leaking or exuding ammunition, all personnel must don protective clothing and equipment before entering the magazine. The doors to the magazine shall be left opened until the hazard has been eliminated. The search to locate and remove the leaking ammunition shall be conducted under the direct supervision of the foreman in charge.

2. Special Inspection Requirements

When conducting inspections of magazines, specific kinds of explosives and ammunition shall be inspected as indicated in the following paragraphs. Any defects noted shall be corrected.

a. Small-Arms Ammunition

Small-arms ammunition shall be inspected to determine that full boxes are properly marked and that the seals are intact. The lids or covers of partially-filled boxes shall be inspected to ascertain that they are securely closed and that the boxes are appropriately marked.

b. Smokeless Powder

All personnel assigned to, or engaged in, the inspection of smokeless powder must be

familiar with the characteristics of decomposed powder. They must also be cognizant of the physical evidence, such as fumes and increases in temperature, which indicates that the powder is in the process of decomposition. Failure to detect a single container of decomposed powder in a magazine may result in a fire and loss of an entire magazine and its contents. Magazines containing smokeless powder shall be inspected to assure that:

(1) Ether or alcohol odors are not present in the magazine. The odor of ether or alcohol in a smokeless powder magazine is an indication that smokeless powder containers in the building are leaking. In sufficient quantity, ether in air is highly flammable and explosive and is readily ignited by sparks, static discharge or excessive heat or friction. Ether and alcohol vapors, when present, must be dissipated by ample ventilation to avoid serious consequences.

(2) The contents of leaking containers when detected must be transferred to serviceable containers. The appearance of the powder may indicate that a surveillance test should be performed.

(3) The containers are not abnormally warm. This would indicate local heating.

(4) The containers are not subjected to moisture or dampness.

(5) Visual magazine samples are placed and maintained in a designated cabinet or rack that is conveniently accessible and adequately lighted when the magazine door is open.

c. Double-Base Propellants

Double-base propellants shall be inspected according to the method prescribed for smokeless powder. In addition, every effort shall be made to detect excessive odors of nitroglycerin or stains on the containers or magazine floor which might be due to exudation or leakage of the nitroglycerin from the powder grains. Any evidence of leakage must be reported immediately to the supervisor in charge.

d. Composite Propellants

Composite propellants shall be visually inspected for the following:

(1) Irregularities in the shape of grain configurations

(2) Cracks in the grain

(3) Air bubbles on the surface of the grain

(4) Odor of ammonia indicating decomposition.

e. Pyrotechnics and Chemical Ammunition

Pyrotechnics and chemical ammunition are frequently characterized by a definite period of service. When this period of service is exceeded, deterioration may be expected. Inspectors shall examine markings closely to determine the dates of manufacture and the expiration dates of storage. They shall also assure that the containers are not rusty, corroded or leaking and that they are tightly sealed and the contents protected against moisture. Special fire-extinguishing agents and safety equipment furnished to the area by the Safety Section and Fire Department must be examined periodically to assure their serviceability.

f. Bulk Explosives

Bulk explosives, such as tetryl, TNT, composition B, composition A, explosive D and black powder, shall be inspected to determine that all containers are in a secured condition and tightly closed. It is important that all containers be properly secured in order to prevent leakage and the entry of moisture, dust, rodents, etcetera. Black powder containers should be examined for rust, loose covers and loosened or ruptured seams. Containers of fulminate of mercury, lead azide, gun cotton and other explosives required to be stored wet with water or water-alcohol mixture shall be examined periodically for leaks, corrosion and damage. These containers shall also be examined to determine that the explosives are actually wet as required.

g. **Fuzes, Primers, Detonators and Similar Initiating Devices**

Fuzes, primers, detonators and similar initiating devices shall be inspected to assure that they are protected from moisture in tightly closed containers and properly segregated in identified lots according to type.

h. **Mortar and Grenade Ammunition**

Mortar and grenade ammunition shall be inspected to determine that it is stored and marked in an approved manner and that all containers are serviceable and securely closed.

i. **JATOS and Rocket Motors**

JATOS and rocket motors shall be inspected prior to use, with due consideration afforded the following:

(1) Evidence of rough handling of the JATO or rocket motor metal parts or packing indicates probable damage to the propellant. When this evidence appears the JATO or rocket motor will be segregated for a complete inspection to determine whether or not they are serviceable. Units declared unserviceable will be dealt with in accordance with established procedures.

(2) A JATO or rocket motor to be inspected shall be moved to a safe distance from similar units and explosives. They shall also be retained at a safe distance from sources of electrical energy capable of inducing current in the JATO or rocket motor circuit before these units are unpacked (see Tables 1-3, 1-4 and 1-5 in the subsection entitled "Destruction of Explosives and Ammunition," pages 1-103 and 1-104. Such inductive sources include power lines, radar units, radio transmitters and other high-powered electrical apparatus.

(3) After their removal from packing materials, JATOS and rocket motors

shall be inspected for the defects described below which may render the JATO or rocket motor unserviceable.

(a) A shorting device (wire, clip or receptacle) shall be included on igniter leads or plugs. For some JATOS, the igniter leads are twisted together to short the ignition circuit in lieu of a shorting device.

CAUTION: If the shorting device is not included or the igniter leads are not twisted together, short the ignition circuit by twisting the igniter leads together before proceeding with the inspection.

(b) Mechanical damage that may render the JATO or rocket motor unserviceable.

(c) The internal presence of moisture, snow, ice, frost and foreign matter will render the JATO or rocket motor unserviceable.

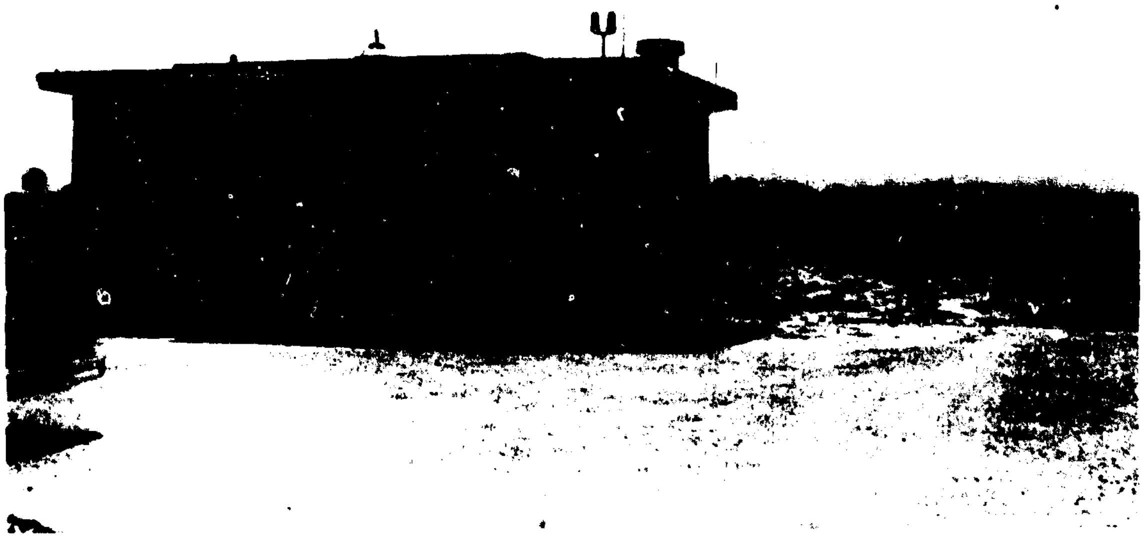
(d) Evidence of propellant damage, that may sometimes be detected by unscrewing shipping plugs, will cause rejection of JATOS or rocket motors.

Such damage may be indicated by the presence of cracked grains, fragments of propellant, nitrous fumes or musty odors. In general, musty odors, particularly in tropical climates, indicate mold and fungus growths.

(e) When required, test continuity of igniter circuit (see facilities for the non-destructive testing of explosives in Figures 1-15 and 1-16).

E. Magazine Safety Precautions

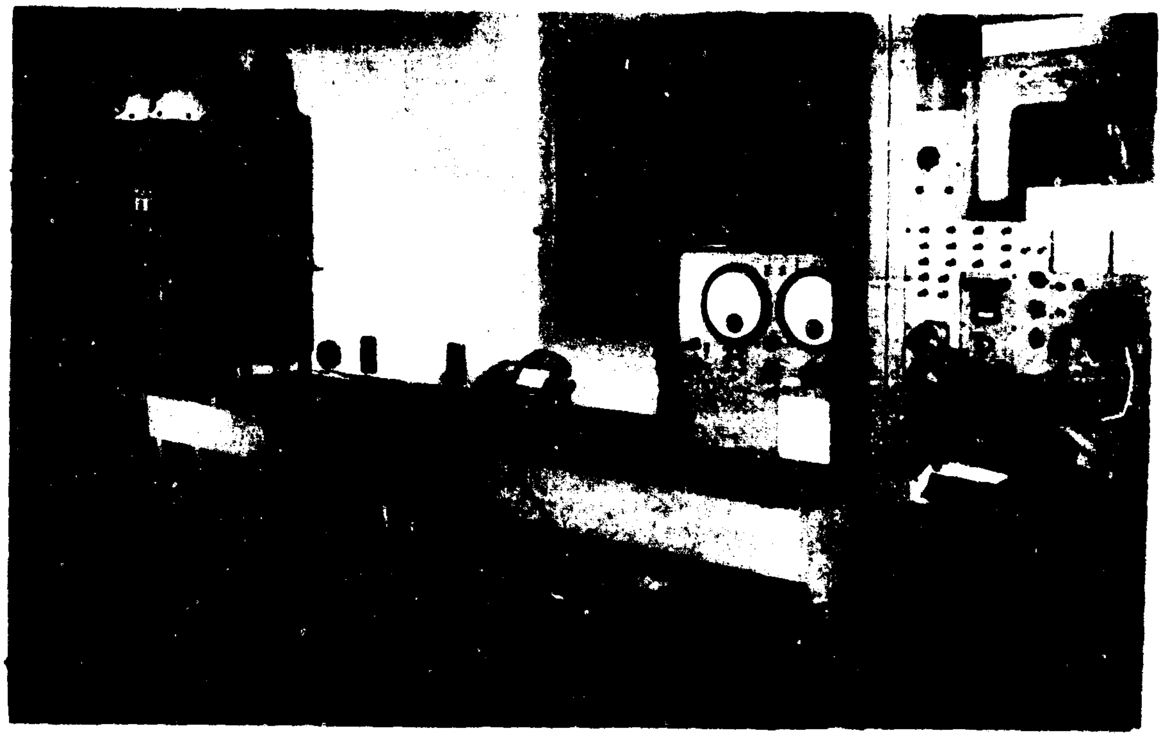
1. Do not store blasting caps in the same magazine with explosives.



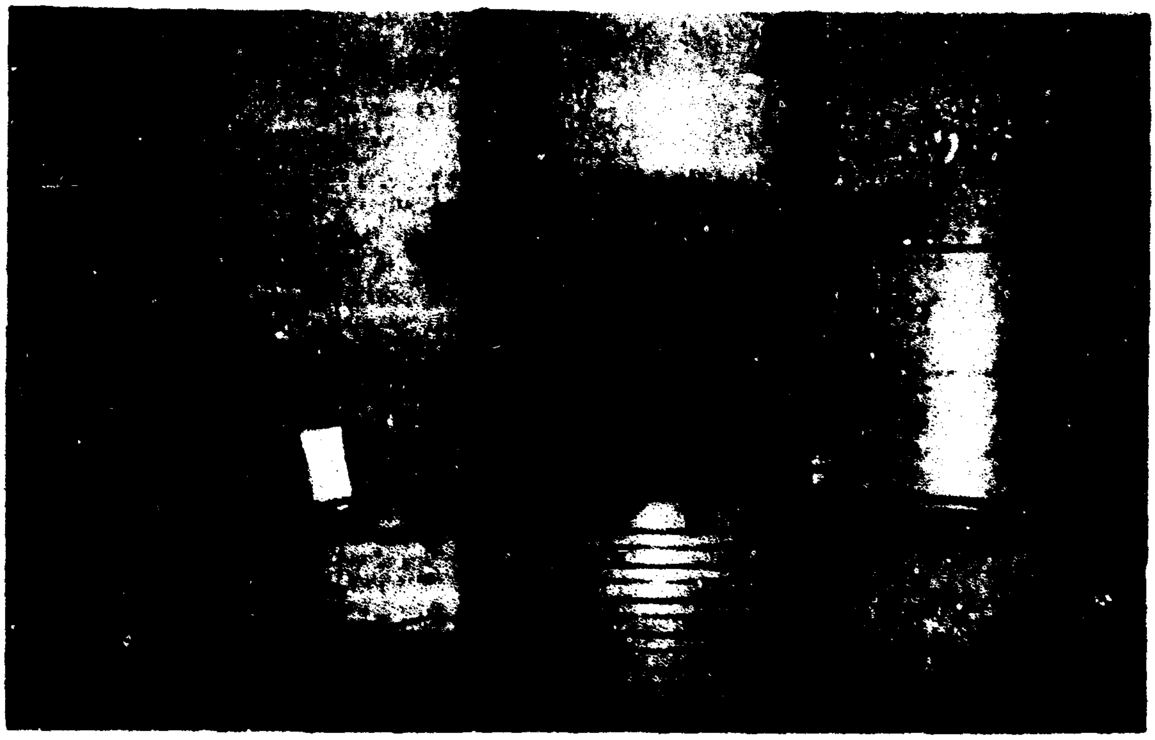
SOLID PROPELLANT TEST AND SURVEILLANCE BUILDING

SOLID PROPELLANT DESTRUCT PAD AND ROCKET PAD

FIG. 1-15 SOLID PROPELLANT TEST AND SURVEILLANCE AREA



INTERIOR VIEW



IGNITER TEST CHAMBER

FIG. 1-16. SOLID PROPELLANT TEST AND SURVEILLANCE BUILDING

2. Do not allow iron or steel tools or any spark-producing or flame-producing devices in a magazine.

3. Do not store miscellaneous non-explosive materials in a magazine containing explosives.

4. Do not open cases of explosives in or within fifty (50) feet of a magazine.

5. Do not wear shoes having exposed nails, metal plates or metal cleats in a magazine. Conductive-type safety shoes are recommended for personnel who work in magazines.

6. Do not store primed cartridges or blocks in a magazine.

7. Do not store empty explosive cases in a magazine.

8. Do not throw, drop or slide cases of explosives into a magazine. Handle each case separately and carefully.

9. Maintain explosives under lock and key at all times. Only one (1) person shall be responsible for their storage and issue.

10. Do not permit smoking within the magazine area which is secured by fencing. Matches, lighters, etcetera, shall be deposited in boxes provided for this purpose before entering the magazine area.

11. Store dynamites and other nitroglycerin explosives top side up, so that the sticks lie in a horizontal position.

12. Keep the floor of a magazine clean at all times.

13. Maintain a fifty (50) foot area around a magazine free of brush, dry leaves and grass.

14. Stack explosives on pallets to provide adequate ventilation and protection against moisture.

15. If artificial light is required in a magazine, use only approved types of electric flashlights or electric lanterns.

16. Separate partially-filled cases of explosives from full cases. Utilize the contents of the partially-filled cases before opening full

cases of the same explosive. Replace the case cover each time after use.

17. Erect a fence around the magazine area to prevent stray animals and unauthorized persons from entering. Signs shall be posted to warn unauthorized persons from entering the magazine area.

18. Stack explosives in a magazine so that the oldest stock of explosives is used first.

19. Firearms, matches, cigarette lighters and any other types of spark-producing devices must not be carried into magazine areas.

20. A record shall be maintained of all items issued from a magazine. Unused explosives shall be returned to a magazine or proper disposition shall be made in accordance with procedures established for that class of explosive.

## VII. DESTRUCTION OF EXPLOSIVES AND AMMUNITION

### A. General

Explosives and ammunition that have become deteriorated or devoid of identification shall be destroyed. Destruction shall be accomplished by burning, detonation or dumping at sea. Burying explosives or ammunition or dumping them into waste pits, wells, marshes, shallow streams or inland waterways is prohibited except when specifically authorized by written instructions.

An Ammunition Disposition Report (ADR) requesting permission to destroy explosives and ammunition must be submitted to the Commander, Air Research and Development Command, through the prescribed channels. Disposition shall not be undertaken until the ADR is approved and returned by the Commander. When disposition is completed the Disposal Officer will sign and date the ADR and return it to the Commander. Deteriorated explosives and ammunition that have been determined to be dangerous to life or property may be disposed of without prior approval from the Commander, ARDC. In these cases, disposition shall be approved by the PAA Superintendent of Missile Propellants at CCMTA. However, an ADR must be submitted in all instances.

### B. Safety Precautions

Safe operations are the major consideration in destroying explosives and ammunition. The "General Safety Precautions" outlined in this MANUAL shall be thoroughly understood and observed by all personnel engaged in demolition operations. The safety precautions that refer specifically to the destruction of explosives and ammunition are discussed below:

1. Selection of a Site for the Destruction of Explosives and Ammunition

   a. By Burning

      The site for the destruction of explosives and ammunition by burning shall be located at the maximum practicable distance from all magazines, inhabited buildings, operating buildings, public highways and railways. Consideration shall also be given to the direction of prevailing winds and to the possibility of mass detonation during burning operations. Wherever possible, natural

barricades shall be utilized between the burning site and operating buildings and magazines. The burning site shall be located from all structures and public thoroughfares by distances comparable to the "inhabited building distances" (see Air Force and Army Quantity-Distance Classes and Tables, pages 1-6 through 1-25).

b. By Detonation

The selection of a site for the destruction of explosives and ammunition by detonation shall be based on the same principles as stated in Par. "a" above. This site shall be not less than 2,400 feet from public railways, inhabited buildings, magazines and operating buildings. When this distance cannot be provided, a pit or trench shall be used to limit the range of flying metal, etcetera. The pit or trench shall be a minimum of four (4) feet deep and covered with at least two (2) feet of earth. The 2,400-foot limitation does not apply where substantially constructed destruction chambers are used. Pits will not be required when the destruction of unserviceable or obsolete ammunition occurs on an artillery range or similar sites. The ammunition shall be covered with earth to limit the range of fragments. This cover of earth should be two (2) feet thick. Demolition charges that are to be covered with earth as specified above shall be provided with detonating-cord leads. These leads shall be long enough to protrude through the earth cover into the open air. Blasting caps are attached to the open ends of the detonating-cord leads and are not subjected to the weight, pressure or friction from the earth cover. Electric-blasting caps shall be located at prescribed distances from transmitters as described in Par. 6.e. on page 1-102 of this subsection. This will minimize the danger of an electric-blasting circuit being energized by stray electric currents.

2. Burning Combustible Rubbish

Combustible rubbish shall not be destroyed at locations where explosives and explosive-contaminated material are destroyed. When separate burning areas cannot be

provided, a part of the explosives destruction-burning ground may be reserved for burning rubbish, provided the two (2) areas are not operated simultaneously. The rubbish-burning area shall be enclosed by a wire mesh or be wetted down prior to the burning of explosives and ammunition in the adjacent area. If a wire mesh is used the mesh shall not be larger than one-half (1/2) inch.

3. Maintenance of Grounds

All dry grass, leaves and other flammable materials within a radius of 200 feet shall be removed from the point of destruction. Fire-fighting equipment for combating grass fires shall be readily available. The ground at the point of destruction shall be wetted down with water at the close of each day's operations. The use of concrete mats for burning or detonation of explosives and ammunition is not permitted.

4. Protection of Personnel

Personnel engaged in demolition work shall always have ample time to reach shelter from the destruction site. The shelter shall provide substantial overhead cover and splinter-proof protection. The signal for detonation shall be given by the individual setting-off the blastings. This signal shall not be given until all personnel in the vicinity have retired to a protective shelter or have reached a safe distance from the destruction area. When an electric-blasting machine is used, the wires shall not be connected to the terminals of the blasting machine until all persons have reached cover. The person in charge of the blasting must be certain that the area is properly cleared of all personnel before initiating the blast. Dependent upon local conditions, temporary or permanent barricades shall be provided and safety distances shall be observed by all persons. Personnel engaged in burning activities shall be provided with fire-resistant outer clothing. During operations, the number of people in the area exposed to the hazard shall be kept to a minimum but never less than two (2). The demolition or burning area shall be provided with telephones or two-way radio communications. See Par. 6.e. and observe quantity

distances listed in Tables referred to therein.

5. Safety Distance Requirements for the Preparation of Primed Charges and Demolition Charges

Personnel shall take adequate precautions to prevent accidental explosions while preparing primed charges for demolition activities. In addition to the general safety precautions currently in force, the following safety rules for the preparation of primed charges and demolition charges shall be strictly observed.

a. The test-burning of safety fuses to determine the rate of burning of the fuse rolls shall be accomplished not less than twenty-five (25) feet from exposed blasting caps or other explosives. The test shall be performed in the direction that the air current is moving.

b. The fuses shall be cut squarely through, approximately 2 or 3 inches from the end of each roll. The short pieces of fuse removed shall be discarded.

c. A one (1) foot length of fuse from each roll shall be cut off and tested to determine the burning time of the fuse. This shall be done at the beginning of each day's operation and whenever a new roll of fuse is used. The rate of burning of rolls of old-type fuse (time-blasting fuse) may vary from approximately 30 to 45 seconds per foot. New-type fuse (safety fuse M700) burns uniformly at forty (40) seconds per foot and is marked at one (1) foot intervals.

d. The supply of blasting caps for the required operation shall be located at a minimum of twenty-five (25) feet from the supply of explosives.

e. The preparation of non-electric primed charges shall be performed not less than twenty-five (25) feet from the supply of blasting caps or other explosives.

f. The fuse used shall be long enough to

permit personnel to walk, not run, to a place of safety before the charge explodes. Fuses less than three (3) feet long or fuses that burn through in less than two (2) minutes shall not be used under any circumstances.

g. A non-electric blasting cap is selected, held open end down and shaken gently to remove dirt or other foreign matter. The desired length of fuse is selected and held in a vertical position. The cap is gently slipped over the fuse until the explosive is in contact with the end of the fuse. Do not turn or twist the fuse in the cap, this action may create a spark. If the fuse will not enter the cap easily, the end of the fuse may be rolled gently between the fingers to facilitate its placement in the cap.

CAUTION: Do not use force. When the fuse is too large it shall be discarded.

h. When the fuse is properly seated within the cap, place a standard-type cap crimper over the cap at the fuse end. Hold the fuse and crimp the cap to the fuse. Crimping by other means is not permitted.

i. No more than ten (10) blasting caps shall be permitted at one time at the site selected for the preparation of primed charges.

j. The priming of explosives will be performed at a distance of not less than twenty-five (25) feet from any storage or operating point involved in the preparation of primers and demolition charges.

k. From 1 to 6 primed charges of explosives may be utilized depending on the size of the site and/or the charges.

l. Primers shall not be prepared, nor shall explosives be primed, in advance of the requirements for their use. Prepared primed charges that are not used shall be expended. Such charges shall not be returned to the explosive storage buildings.

m. A limited quantity of explosives sufficient to meet the requirements of the operation involved shall be brought to the demolition site.

6. Electrical Hazards

Special precautions shall be taken when using electric-blasting caps and electric-blasting circuits during demolition operations. These precautions are discussed below:

a. Electric-blasting caps and electric-blasting circuits may be energized to dangerous levels from outside sources. These sources include static electricity, induced electric currents, radio communication equipment, high-tension wires, etcetera. Safety precautions, therefore, shall be taken to reduce the possibility of a premature initiation of the electric-blasting caps and explosive charges.

b. The shunt shall not be removed from the lead wires of the blasting cap until the moment the lead wires are connected to the blasting circuit. The individual who removes the shunt shall ground himself prior to performing this operation, in order to prevent accumulated static electricity from firing the blasting cap.

NOTE: When the blasting cap is tested prior to priming the charge, the lead wires must be short-circuited immediately after the test. This is done by twisting the bare ends of the wires together.

The wires shall remain short-circuited until the time they are connected to the blasting circuit.

c. When uncoiling the lead wires of blasting caps, the cap shall be held by the wires approximately six (6) inches from the cap. The cap shall never be held directly in the hand. The lead wires shall be straightened out as far as necessary by hand. They shall never be thrown, waved through the air or snapped

as a whip to loosen the wire coils.

d. Both ends of the firing wires shall always be shorted or twisted together and connected to the ground, except when actually firing the charge or testing the circuit. The connection between the blasting caps and the circuit-firing wires shall not be made unless the power end of the circuit leads (firing wires) are shorted and grounded.

e. The premature ignition of electrically-initiated devices, such as squibs and blasting caps in a radio frequency environment, constitutes a real hazard. Radio and radar transmitters and other radio frequency energy-generating systems create a field of electromagnetic energy in the air surrounding their antennas. When the lead wires of squibs and blasting caps form a resonant antenna enough energy may be picked up to cause ignition of these items. Tables 1-3, 1-4 and 1-5 indicate the minimum distance based on the power of transmitters beyond which it is safe to conduct electrical-explosive operations.

f. There are two possible courses of action that can be taken when it is necessary to perform blasting operations at distances less than those shown in the Tables noted in Par. "e" above.

(1) Use a non-electric blasting system. This procedure is preferred in these instances because there is no danger of a premature detonation being caused by radio frequency currents.

(2) Use an electrical-blasting system but observe the following precautions to minimize the possibility of a premature detonation of the electric-blasting cap by induced radio frequency currents:

(a) Observe all the usual safety precautions governing electrical-blasting operations.

(b) "Snake" (not in a straight line) all firing wires.

TABLE 1-3 MINIMUM DISTANCES VERSUS FM MOBILE TRANSMITTERS*

| TRANSMITTER POWER (WATTS) | MINIMUM DISTANCE (FEET) |
|---|---|
| 1-10 | 5 |
| 10-30 | 10 |
| 30-60 | 15 |
| 60-250 | 30 |

NOTE: Induced currents resulting from mobile-type radio transmitters up to five (5) watt RF output can be disregarded as a safety hazard.

TABLE 1-4 MINIMUM DISTANCES VERSUS RADIO TRANSMITTERS*

| TRANSMITTER POWER (WATTS) | MINIMUM DISTANCE (FEET) |
|---|---|
| 0-30 | 100 |
| 30-100 | 200 |
| 100-250 | 500 |
| 250-1,000 | 1,000 |
| 1,000-5,000 | 2,000 |
| 5,000-50,000 | 5,000 |
| Above 50,000 | 10,000 |

TABLE 1-5 MINIMUM DISTANCES VERSUS RADAR TRANSMITTERS*

| TRANSMITTER POWER (WATTS) | MINIMUM DISTANCE (FEET) |
|---|---|
| 5-25 | 100 |
| 25-50 | 150 |
| 50-100 | 220 |
| 100-250 | 350 |
| 250-500 | 450 |
| 500-1,000 | 650 |
| 1,000-2,500 | 1,000 |
| 2,500-5,000 | 1,500 |
| 5,000-10,000 | 2,200 |
| 10,000-25,000 | 3,500 |
| 25,000-50,000 | 5,000 |
| 50,000-100,000 | 7,000 |
| 100,000 and up | 7,000 |

* Tables taken from OOAMA Munition Letter No. 136-6-23, dated 16 September 1959, entitled "Airmunitions and Explosive Safety."

(c) A twisted wire such as W-110-B or WD-1-TT shall be used.

(d) The full length of all cap leads shall be evenly twisted when they are removed from their original containers.

(e) The number of blasting caps shall be kept to a minimum, preferably one (1).

g. Electric-blasting caps shall be connected to the firing circuit before they are placed in or connected to the main charge. This procedure will minimize damage should an electric-blasting cap prematurely detonate due to stray currents. It will also serve as a test circuit for determining the presence of a dangerous quantity of radio-frequency current.

WARNING: Individuals connecting the caps shall utilize all available cover to protect themselves when completing the circuit. The distance between the individual and the blasting cap shall be at least the len[illegible] the cap leads. Als[illegible] [illegible]du[illegible] shall keep [illegible] [illegible]d the blasting cap [illegible] [illegible]g the connection.

h. Blasting or demolition operations shall not be conducted during an electrical storm or during a dust, sand or snow storm severe enough to produce atmospheric static. Blasting or demolition operations will be cancelled upon notice that such a storm is approaching. All operations shall be suspended, cap wires and lead wires shall be short-circuited and all personnel must be vacated from the demolition area to a safe location.

i. Prior to making connections to the blasting machine, the firing circuit shall be tested with a galvanometer for electrical continuity. The individual assigned to make the electrical connections shall not complete the circuit at the blasting machine or panel, nor shall he give the signal for detonation until he is assured

all persons in the vicinity have evacuated to a safe location. The blasting machine or its actuating device shall be in this individual's possession at all times during the demolition operation. When a panel is used, the switch must be locked in the open position until ready to fire. The key to the panel switch shall remain in the possession of the responsible person during the operation.

7. Removal of Explosives and Ammunition from Containers

Explosives and ammunition to be destroyed by burning shall be removed from containers, since any attempt to burn explosives or ammunition even under slight confinement may result in an explosion or detonation. Exuding (leaking) dynamite in boxes is an exception and shall be burned without opening the boxes.

8. Determining the Quantity to be Destroyed

The quantity of material to be destroyed at one time will depend upon local conditions. This quantity will be carefully determined, beginning with a limited number and gradually increasing the number until the maximum can be destroyed without causing damage to surrounding property or disturbance to civilian areas. The responsible individual will make certain, before he gives the signal for detonation, that there are no unauthorized persons in the danger area and that all authorized persons are protected by adequate distance and cover.

9. Collection of Unexploded Ammunition

A search of the surrounding grounds shall be made after each blast and any material which has been thrown from the pit undetonated shall be collected and included with the next charge to be destroyed. Ammunition that has been subjected to an explosion may be hazardous to handle. When such items are discovered the duds shall be detonated in the place where they are found. Fuzed ammunition blown from a pile or pit and not detonated shall not be collected

due to the possibility of the fuze being activated. These items shall be detonated in the location where they are found.

10. Segregation of Material Awaiting Destruction

Explosives or ammunition awaiting destruction shall be separated by the intraline distance (see Definitions) from the point of destruction. They shall be protected from grass fires, burning embers and flying fragments. All dry grass, leaves and other flammable material within a radius of fifty (50) feet shall be removed from the explosive material.

11. Caution Against Unintentional Ignition

In repeating the burning operation, care shall be taken to guard against material being ignited from burning or smoldering residue or from heat retained in the ground. Burnings shall not be repeated on previously burned-over areas until a period of at least twenty-four (24) hours has elapsed.

12. Improvising

The use of improvised methods for exploding blasting caps is prohibited.

13. Misfires

In case of a misfire, personnel shall not approach the pit, trench or point of detonation until a period of thirty (30) minutes has elapsed. No more than one (1) qualified person shall be permitted to examine the misfire.

14. Use of Trained Personnel

Destruction of ammunition shall never be attempted by inexperienced or untrained personnel. The number of personnel engaged in these operations will be kept to a minimum. More than one (1) person shall be present during demolition operations.

15. Guarding Demolition Area

Guards, safety signals and warning signs shall be used to restrict unauthorized personnel from danger areas during destruction operations.

16. Additional Instructions

In the absence of specific regulations or information covering any phase of the destruction of explosive material, instructions will be requested from the Commander, ARDC, through the prescribed channels.

C. Bulk Explosives

1. Black Powder

The safest method to destroy black powder is to dump it in a stream or body of water, provided it is not prohibited by law. When no authorized body of water is convenient, it may be burned. Only tools of wood or non-sparking metal shall be used in opening the containers (see Fig. 1-1, page 1-47). The contents of only one (1) container shall be burned at a time; no quantity should exceed fifty (50) pounds. The powder must be removed from the container and spread out on the ground in a train about two (2) inches wide. The individual parts of the explosive train shall be separated by a minimum distance of ten (10) feet. To ignite the powder bed, use a train of flammable material, such as excelsior, approximately twenty-five (25) feet long. This material shall be placed so it will burn with the powder in the direction that the wind is blowing. The powder train allows sufficient time for personnel to safely withdraw from the area. If the powder were consolidated into one mass, the flare would be so sudden and intense that all personnel would be endangered. Empty black powder containers shall be thoroughly washed on the inside with water, since serious explosions have occurred with supposedly empty black-powder cans. Safety precautions, particularly those outlined in paragraph B of this subsection of the MANUAL, shall be observed. Wet black powder may resume its explosive properties upon drying. Ammunition items which contain small quantities of black powder such as fuzes, pyrotechnic items, target practice rounds, etcetera, are to be disposed of in accordance with prescribed procedures for the particular items involved.

2. TNT, Composition A, Composition B and Composition C Series, Explosive D, Tetryl, Tetrytol, Pentolite and RDX

These explosives shall be destroyed by burning. They must not be dumped into water. Although they are not soluble to a great degree, they do poison the water. The explosive to be burned shall be removed from containers and spread in a thin layer, not more than three (3) inches thick on a layer of flammable material such as excelsior. The train of flammable material shall be arranged as stated in Par. 1 above. Safety precautions outlined in Par. B shall be observed. No attempt shall be made to burn high explosive in lump form. Some of these explosives that normally burn when unconfined have been known to detonate during destruction by burning.

CAUTION: RDX shall be burned wet with water to prevent detonation.

3. Solid Propellant

Quantities of solid propellant may be destroyed safely when the propellant is removed from the containers and spread out on the bare ground in a train 1 to 2 feet wide and not more than three (3) inches thick. A train of flammable material approximately twenty-five (25) feet long and arranged as stated in Par. 1 above, shall be used to ignite the propellant. This allows personnel sufficient time to escape the intense heat generated when a solid propellant burns. Safety precautions outlined in Par. B above shall be observed.

4. Dynamite

Not more than one hundred (100) pounds of dynamite shall be destroyed by burning at one time. Dynamite cartridges, except frozen cartridges, to be destroyed by burning shall be slit lengthwise into halves with an ordinary knife. Knives with closing blades shall not be used. The slit cartridges are placed in a single layer, not larger in width than the length of one (1) cartridge. They are placed on hay, excelsior or other combustible material. The combustible train, arranged as stated in Par. 1 above, shall be of sufficient length to allow personnel to

reach cover or a safe distance before the dynamite begins to burn. The dynamite containers shall be burned at the same time. Dynamite awaiting destruction shall be shielded from the direct rays of the sun. Sixty (60) per cent dynamite frequently detonates after burning a short period of time. Frozen dynamite is more likely to detonate during burning than normal cartridges. Destruction of dynamite by detonation may be accomplished when the location will permit this method of destruction. Care in priming must be taken to assure complete detonation of the quantity to be destroyed.

5. Other Explosives

Detonation is considered to be the best method of destroying highly-sensitive explosives such as mercury fulminate and lead azide. The bags containing the explosives shall be kept wet with water while being transported to the demolition area. A number of bags (the number shall be consistent with safe operation) shall be removed from the container and carried to the destruction pit. The bags are placed in the pit in intimate contact with each other. Blasting caps are used to initiate the explosives. The remaining explosives shall be kept behind a barricade affording overhead protection during the operations. The barricade shall be located at a distance that will assure safety.

D. Separate-Loading Propelling Charges

Propelling charges with igniters may be burned without slitting but in all cases the igniter-protector caps will be removed from the charges to be burned. Protection shall be provided against possible explosion and projection of burning particles. Propelling charges shall not be stacked but will be placed in a single layer for burning. Core-igniter type charges shall be spaced a distance of one (1) charge from each other.

E. Rockets

Rocket duds loaded with high explosives shall be detonated in the location where they are found. High

explosive and practice rockets awaiting destruction shall be destroyed as follows:

1. Rocket heads will be disassembled from complete rounds and destroyed in the same manner as a separate-loading shell. The rocket head to be destroyed shall be placed on its side in a trench or pit approximately four (4) feet deep. The required quantity of explosive (1/2 pound or less of Comp. C per round of ammunition) shall be placed in contact with the side of the rocket head. The explosives shall be held in position by earth that shall be packed around the rocket head. If the explosive used is a TNT block, it shall be placed on its side. When two (2) blocks are used, one is placed on top of the other. When three (3) blocks are used. two (2) are placed close together on the rocket head and the third block is placed on top. When five (5) blocks are used, there will be two (2) layers of two (2) blocks each, with the fifth on top. The demolition blocks are detonated by means of an electric-blasting cap that is wired to a blasting machine. They may also be detonated by a safety fuse attached to a non-electric blasting cap.

2. When disassembly of the rocket head from the motor is not practicable, the complete round may be destroyed by detonation. Detonation of the complete round must be performed in a manner that will assure simultaneous and complete destruction of both the rocket head and the motor.

3. When a rocket motor is to be destroyed, the nozzle or nozzle plate shall be removed and the igniter and propellant withdrawn and destroyed in accordance with Par. D, "Separate-Loading Propelling Charges." Rocket motors larger than six (6) inches in diameter will be considered as JATOS and destroyed accordingly.

F. JATOS

When possible, the nozzle and head-end of the JATO shall be separated from the motor. The igniter and propellant shall be removed and burned in accordance with Par. D, "Separate-Loading Propelling Charges." If it is impossible or impracticable to remove the propellant, the JATO shall not be destroyed until special instructions are received from the Commander, ARDC.

G. Small-Arms Ammunition

Small-arms cartridges shall be destroyed in a pit approximately six (6) feet square and four (4) feet deep. A chute consisting of a piece of two (2) inch pipe shall be provided for this operation. This chute shall be sloped at an angle that will permit the ammunition to slide down the chute and into the pit. The chute shall be placed so one end is over the center of the pit and the other end behind a barricade. Precautions shall be taken to baffle the open end behind the barricade so the operator cannot look through the chute. A fire shall be built in the pit and the pit shall be covered with a piece of sheet iron or other suitable material to confine flying fragments. The cartridges shall be fed into the fire through the chute with care taken to prevent an accumulation of unexploded ammunition in the pit. A furnace or burning kettle designed for the destruction of small-arms ammunition by burning is also satisfactory.

H. Small Components, Except Primers

These components, which include fuzes, boosters, detonators, firing devices and similar material, may be destroyed either by burning or by detonation.

Relative to the destruction by burning, the same instructions given in Par. G. "Small-Arms Ammunition" shall apply to these components. Caution shall be exercised when placing components in the fire, since normal action cannot be expected under intense heat.

The sound of an explosion must be heard for each component placed in the fire. Another component shall not be placed in the fire until the explosion of the previous one has been heard. An unusual delay in the explosion of a component shall not be investigated until the fire has burned out and the pit is cold.

When these components are to be destroyed by detonation, they shall be placed together, in small numbers, in an open container. The number to be destroyed at one time shall be dependent upon the type and kind of components. The container and components shall be placed in a pit or trench four (4) feet deep. One or more TNT blocks shall be placed on top of each container and in contact with the components. These blocks shall be fitted with a type-II special electric-blasting cap or with a type-I special non-electric blasting cap and safety fuze. The pit shall then be covered with a layer of logs and earth or other suitable cover and the components shall be detonated in accordance with safety regulations.

I. Primers

Large primers, 100-grain or more, may be destroyed by burning in accordance with the instructions for the destruction of small-arms ammunition as outlined in Par. G, "Small-Arms Ammunition." Primers, other than small-arms cartridge primers, are placed in the fire one at a time. Large primers shall be destroyed only in this manner since they are subjected to explosion "en masse" when destroyed by burning in large quantities.

Primers, except the 100-grain or larger primers, may be burned in a trench approximately two (2) feet deep and one (1) foot wide. The trench shall be of sufficient length to accommodate the number of primers to be burned at one time. The trench shall be prepared with a sufficient quantity of excelsior or similar combustible material to insure a fire throughout the length of the trench. The primers shall be removed from boxes and placed on the excelsior before it is lighted. Pastboard cartons need not be opened before they are placed in the trench. A piece of sheet metal shall be placed over the trench to confine fragments as much as possible. After the primers and cover are in place, a train of combustible material leading into the pit shall be prepared and lighted. Personnel shall then take cover or withdraw to a safe distance from the area of destruction.

A tank or kettle with a small mesh screen over the top may be utilized for the destruction of a smaller number of primers. The primers are exploded by a fire that is built underneath the tank or kettle. A convenient set-up for this purpose is a cylindrical-steel tank that has been cut in half, longitudinally. The open side is placed on a steel grating that will retain the primers in the bank. A twelve (12) inch hole is cut in the top center of the half-cylinder tank. A chute or pipe, large enough to accommodate the largest primer shall be inserted into the hole. The chute shall enter the hole at an angle steep enough to allow the primers to slide down. A hole for a smoke stack to provide draft is also cut in the half-cylinder tank and a stack is inserted therein. The entire arrangement is rested on stone, brick or earth supports in order that a fire may be built underneath. About fifty (50) primers are slid down the chute and onto the grate for each burning operation. Packing material, if flammable, need not be removed from the primers.

The smaller end-vent primers may be destroyed by burning in a fireplace. A steel-mesh basket of primers may be pulled onto a grating over the fireplace from behind a barricade. The fire shall be

started before the basket of primers is pulled over it. When all primers have been fired, the basket shall be pulled off, emptied, cooled, refilled and again pulled over the fire.

Stocks of primers awaiting destruction shall be located not less than 300 feet from the burning operations. Great care shall be exercised to protect the pile from accidental ignition by flying fragments or sparks. Stocks shall be limited to a one (1) day supply. Other applicable regulations contained in Par. B, "Safety Precautions," on page 1-96 shall be strictly observed.

J. Grenades

1. General

Grenades may be destroyed by burning or detonation. Strict compliance with applicable regulations stated in Par. B, "Safety Precautions," is essential for the protection of personnel and property. Destruction by detonation should generally be applied to high-explosive grenades, whereas, destruction by burning is applied generally to other types of grenades.

2. Destruction by Detonation

Not more than twenty (20) HE grenades shall be placed in a destruction pit; the pit shall be approximately four (4) feet deep. The grenades shall be placed in close contact. Three (3) 1/2-pound TNT blocks, taped together, shall be placed on top of the pile. A type-II special electric-blasting cap arranged for wiring to a blasting machine or a type-I special non-electric blasting cap fitted with several feet of safety fuse shall be taped to one of the three blocks. The grenades and TNT blocks (with lead exposed as described in Par. B.1.b., page 1-97) shall be covered with a layer of lightly tamped earth about one (1) foot thick. This is accomplished in order to obtain the maximum efficiency from the explosion of the TNT blocks. The pit shall then be covered as described in Par. B, "Safety Precautions," on page 1-96.

3. Destruction by Burning

A pit two (2) feet square by three (3) feet deep with a loosely fitted steel

plate or heavy board cover shall be provided. Grenades (other than HE loaded) shall be placed in the fire one (1) at a time. Other grenades shall not be placed in the fire until the previous grenade has exploded. Care shall be exercised in placing explosives into the fire as normal destruction cannot always be expected when the grenades are subjected to intense heat. An unusual delay in the explosion of a grenade shall not be investigated until the fire has burned out and the pit is cold. An inclined chute baffled at the open end may be utilized in lieu of dropping grenades singly and covering the pit with the steel plate or heavy board cover each time.

K. Pyrotechnics

1. General

Pyrotechnics, except photoflash bombs and parachute flares, shall be destroyed in accordance with the instructions for burning primers (see Par. I, "Primers," page 1-113). Loose pyrotechnic materials shall be burned under the same conditions as black powder and the same precautions shall be observed (see Par. C.1., "Black Powder," page 1-108).

2. Parachute Flares

Parachute flares shall be destroyed by burning in the open. The individual flares must be located at least four (4) feet apart and placed on top of a layer of combustible material. After lighting the train of combustible material, personnel shall take cover at a safe distance. Personnel shall face away from the fire to avoid injury to their eyes from the extreme brilliance of the flame.

3. Photoflash Bombs

Photoflash bombs are dangerous and shall be handled with care. They shall be destroyed by the use of TNT blocks, similar to the procedure for artillery shells. (This procedure is given in T.O. 11A-1-37.) Due to the thin case, one (1) 1/2-pound block of TNT is sufficient to accomplish destruction. Strict compliance with the applicable regulations of Par. B, "Safety Precautions," is essential.

NOTE: Due to the brilliance of the flash of exploding photoflash bombs, personnel engaged in the destruction operation shall protect their eyes.

## REVISION SHEET

1. Basic Communication — February 1960

Section 2

# EXPLOSIVES AND AMMUNITION

## I. GENERAL

Missile Weapons Systems are so closely correlated to explosives and ammunition that an understanding of one must lead to an understanding of the others. The complete functioning and composition of all component missile parts must be understood by all personnel handling explosives and ammunition. For the component parts of any missile to function properly at the time and place specified, it is necessary to employ different types of explosives and ammunition, each having a specific role, either as a propellant, booster, sustainer, igniter, destructor, detonator, squib, explosive bolt, etcetera.

An explosive is defined as any substance or mixture of substances that will produce, upon release of its potential energy, more stable substances. These substances are mainly gases. When these chemical compounds or substances are subjected to initiating impulses or agents such as flame, spark, heat, impact or friction (whether applied mechanically, electrically or atomically) they undergo chemical and physical transformation at speeds varying from extremely rapid to virtually instantaneous. This results in a sudden and rapid development of very high pressure in the surrounding medium. This transformation will create more stable compounds, accompanied by a considerable and rapid rise in pressure. The generation of a larger volume of gas than originally present and by the evolution of large quantities of heat and other forms of energy causes this rapid rise in pressure with consequent expansion of the surroundings. The transformation accomplishes work of a useful or destructive character, depending on the measure of control exercised over the reaction. Modern military and commercial explosives include three (3) fundamental types, namely; mechanical, chemical and atomic. This MANUAL will discuss only the chemical explosives.

Ammunition is defined as "all the components, and all explosives in any case or contrivance prepared to form a charge, complete round or cartridge for cannon, howitzer, mortar, small arms or for any other weapon, torpedo warhead, mine, bomb, depth charge, demolition charge, fuse, fuze, detonator, projectile, grenade, guided missile and rocket; all signalling and illuminating pyrotechnic materials; and all chemical warfare materials."

This Section lists many of the types of explosives and ammunition used in the rocket and missile programs and elaborates on those in use at Cape Canaveral.

The chemical explosives included in this Section consist of four (4) types:

1. Low or deflagrating explosives

2. Solid propellants

3. Pyrotechnic compositions

4. High or detonating explosives

The distinction between low explosives and high explosives is not clearly defined. A few low explosives under proper conditions of fineness and packing confinement may detonate upon ignition, while a few high explosives when unconfined or compressed under very extreme pressures may simply burn when ignited by a flame. Also many texts classify solid propellants as low explosives, however, in this MANUAL solid propellants will be treated as a separate entity because of the many new developments in propellant compositions.

Black powder and squib compositions will be discussed as low explosives, while high explosives will include the primary and secondary explosives. A brief treatise of pyrotechnic compositions will also be presented.

The dissertation on ammunition will include igniters, ordnance-explosive devices, rockets and rocket motors.

A continuous change of conditions and situations in several fields of science and engineering requires many different types of explosives. The operational levels and burning characteristics of these explosives range from the low-pressure explosives (black powder and propellants) to the highest high-pressure explosives (dynamites and high explosives). Therefore, a great variety of explosives have been designed and used in the various scientific fields. It has been possible to fulfill the many needs for explosives that require specific characteristics by using only a relatively few explosives and chemical ingredients. This task has been accomplished by combining different combinations of ingredients that exhibit different physical properties (density, granulations, etcetera).

Many of the explosives and ingredients shown in Table 2-1 have been mixed or consolidated with a chemical additive to produce the many new high-energy solid fuels being used in the rocket and missile fields.

TABLE 2-1 - COMMON EXPLOSIVES AND INGREDIENTS

| Military Uses | Commercial Uses |
|---|---|
| **LOW EXPLOSIVES** | |
| Smokeless Powder, Nitrocotton<br>Black powder (potassium nitrate, sulfur, charcoal)<br>DNT (dinitrotoluene)<br>Nitroguanidine | Smokeless powder<br>Nitrocotton<br>DNT (dinitrotoluene)<br>Black powder (sodium nitrate, sulfur, charcoal) |
| **PROPELLANTS** | |
| Single-base propellants:<br>Pyrocellulose powder<br>Ethyl cellulose powder<br>Flashers and smokeless powder<br>Small arms powder<br><br>Double-base propellants:<br>Rolled powder<br>Cordite powder<br>Nitroguanidine (triple base)<br>Multi-and single-perforated stick powders<br>Ballistite powder<br>Ball powder<br>Cast double-base propellants<br><br>Composite propellants:<br>Polysulfide-Perchlorate<br>Polyurethane-Perchlorate<br>PVC Plastisol-Perchlorate<br>Polyester-Perchlorate<br>Butadiene-MVP-rubber nitrate | Very few propellant compositions are used in the commercial explosive field |

TABLE 2-1 - COMMON EXPLOSIVES AND INGREDIENTS (Continued)

| Military Uses | Commercial Uses |
|---|---|
| **PYROTECHNIC COMPOSITIONS** | |
| Illuminating projectiles<br>Trip flares<br>Airport flares<br>Parachute flares<br>Reconnaissance flares<br>Aircraft landing flares<br>Bombardment flares<br>Photoflash bombs<br>Photoflash cartridges<br>Pyrotechnic signals<br>Tracers<br>Communications<br>Smoke signals<br>Simulated ammunition | Illuminating projectiles<br>Airport flares<br>Aircraft landing flares<br>Pyrotechnic signals |
| **PRIMARY OR INITIATING HIGH EXPLOSIVES** | |
| Mercury Fulminate<br>Lead Azide<br>Diazodinitrophenol (DDNP)<br>Lead Styphnate<br>Nitromannite | Mercury Fulminate<br>Lead Azide<br>Diazodinitrophenol<br>Lead Styphnate<br>Nitromannite |

TABLE 2-1 - COMMON EXPLOSIVES AND INGREDIENTS (Continued)

| Military Uses | Commercial Uses |
|---|---|
| **SECONDARY HIGH EXPLOSIVES** | |
| TNT (trinitrotoluene) (Bursting) | NG (nitroglycerin) |
| Tetryl (trinitrophenylethyl-nitramine) (Booster) | AN (ammonium nitrate) |
| RDX (cyclotrimethylenetri-nitramine) (Bursting) | TNT |
| PETN (pentaerythritol tetranitrate) (Booster) | DNT |
| Ammonium Nitrate | Nitrostarch |
| Ammonium Picrate (explosive D) (Bursting) | PETN |
| Picric Acid (trinitrophenol) | Tetryl |
| DNT (dinitrotoluene) | |
| EDNA (ethylenediamine-dinitrate) | |
| **NON-EXPLOSIVE INGREDIENTS** | |
| Aluminum | Metal Nitrates |
| Waxes | Metals (aluminum ferro-silicon) |
| Diphenylamine | Wood pulps, metals, other combustibles |
| Metal nitrates | Paraffin, other hydro-carbons |
| Mononitrotoluene | Chalk, diphenylamine, wax, sulfur, carbon |

## II. EXPLOSIVE TRAIN

The explosives used in rocket motors must be comparatively insensitive to impact in order to insure safe handling in transit and storage. Sensitive explosives, that can be detonated by the impact of a firing pin or an electric charge, generally are safe to handle when they are in small quantities, highly compressed and enclosed in a metal capsule. They are used in that form in fuzes and primers. The small spit of flame from a primer will not fully detonate a large charge of comparatively insensitive explosive, therefore, it is necessary to interpose a medium quantity of explosive of medium sensitivity. Explosive charges arranged in the order of very sensitive to medium sensitive to insensitive explosives constitute an explosive train.

The low explosive or propelling-explosive charge train in a rocket motor consists of the primer, igniter and propelling charge. This type of explosive train is used for the ejection or propulsion of a body or a missile from a launching location. It is also used in small arms, cannon and artillery ammunition.

Frequently in missile armaments or jet propulsion weapons, such as rockets and JATOS, a series of explosive elements including primer, detonator and booster make up the igniter. The igniter and propelling charge comprise the explosive train.

A bursting-charge explosive train, which usually makes up the warhead, consists essentially of a primer, a detonator, a booster and the bursting charge. A delay element sometimes is included in the fuze to meet requirements for delay action.

Figure 2-1 illustrates various types of explosive trains.

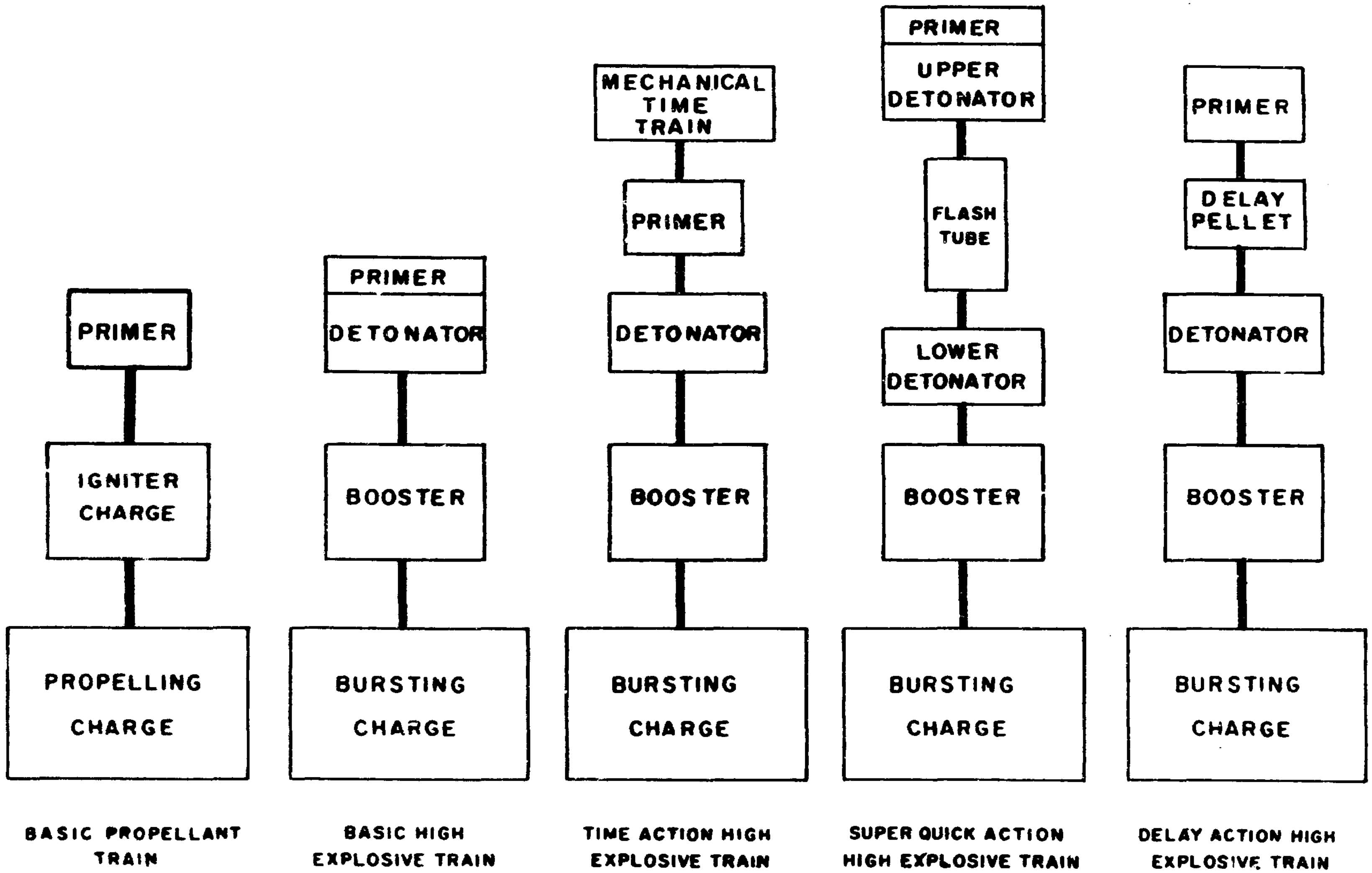



FIG. 2-1: SCHEMATIC ARRANGEMENT OF COMPONENTS OF EXPLOSIVE TRAINS

III. LOW EXPLOSIVES

A. General

The difference between the various types of explosives is based primarily upon their relative speed of decomposition. A group of explosives, classified as low explosives, is the result of controlling combustion speeds by means of granulation, loading density and confinement (surrounding pressure).

Low explosives are mostly solid-combustible masses that will, upon ignition, exhibit a burning action rarely exceeding 0.25 meters per second and will not normally explode. The action of slow burning of the solid combustibles without shattering or exploding is termed "deflagration." Low explosives are frequently referred to as "deflagrating" explosives.

The burning phenomenon of low explosives does not proceed through the mass of the material but burns in layers parallel to the surface until all the material is consumed. Large volumes of gas evolve in a definite and controllable manner. The burning phenomenon and decomposition of high explosives is instantaneous and produces a shattering effect. In low explosives only a slight shattering effect is exhibited.

The principal characteristics of low explosives are:

1. Controlled burning rate
2. Instantaneous ignition and slow combustion
3. Stability over extended periods of storage
4. Balanced formulation for complete combustion producing a minimum residue and weapon erosion
5. Minimum toxicity and explosion hazard
6. Capability of withstanding mechanical shock incident to handling, loading, transporting and storage.

B. Black Powder

1. General

The oldest, best known and most widely used low explosive is black powder. Black powder is classified as a low or deflagrating explosive. It is differentiated from high or detonating explosives

because of its progressive slow burning over a relatively sustained period of time in contrast to detonating explosives that decompose practically instantaneously. Black powder is the generic name applied to an intimate, uniform mechanical mixture of charcoal, sulfur and potassium nitrate. The term "black powder" also includes compositions of bituminous coal instead of charcoal and sodium nitrate in place of potassium nitrate.

Previous to the development of nitrocellulose propellants, black powder consisting of potassium nitrate was the only propellant and explosive available. Potassium nitrate is used in most military black powders. While no longer used as a military propellant, black powder finds application in the ignition of smokeless powder, time fuzes, saluting charges, squibs, smoke-puff charges and catapult charges. The commercial black powder containing sodium nitrate is used in igniters for rockets, JATOS and missile boosters and sustainers.

2. Composition

The composition of black powder containing potassium nitrate, charcoal and sulfur has remained essentially unchanged for 400 years. Any modification of the ingredients in proportionate quantities of 75:15:10 has been found to result in the powder burning more slowly or producing less effect. Standard black powder contains seventy-five (75) per cent potassium nitrate, fifteen (15) per cent charcoal and ten (10) per cent sulfur. Its auto-combustion yields nitrogen, carbon dioxide, carbon monoxide, potassium carbonate, potassium sulfate and potassium sulfide.

3. Properties

a. Form and Appearance

Black powder varies in form and appearance from a very fine black powder to dense pellets. These pellets may be black or have a grayish-black color because of a polished graphite-glazed surface.

b. Granulations

Military-black powder is manufactured in a range of grain sizes. Each is identified by designation, grade, symbol or name.

c. Ignition

Black powder ignites spontaneously at approxi-

mately 300°C (540°F). It develops temperatures of combustion from 2,300° to 3,800°C (4,172° to 6,872°F). These high temperatures cause erosion in the bore of weapons. Black powder is hygroscopic and subject to rapid deterioration when exposed to moisture. If kept dry, it retains its explosive properties indefinitely. It is one of the most dangerous explosives to handle because of its sensitivity and ease of ignition from heat, friction, spark, flame or shock.

d. Burning Rate

The type of charcoal used in the manufacture of black powder affects the burning rate of the powder. Black powder burns much more rapidly when made from willow or alder charcoal than from oak charcoal. Increase in the percentage of nitrate, with corresponding decrease in percentage of charcoal, causes a decrease in the burning rate.

e. Sensitivity

Black powder is less sensitive than tetryl, as proved by impact tests and undergoes no ignition in the pendulum friction test with a steel shoe. In the sand test it crushes no sand when ignited by a flame and only eight (8) grams when initiated by tetryl or PETN. Having an explosion-temperature test value of 457°C it is also relatively insensitive to non-radiant heat energy. Its high degree of accidental explosion hazard is attributable to its great sensitivity to ignition by flame, incandescent particles or electric spark. The ballistic pendulum test shows black powder to be fifty-five (55) per cent as powerful as TNT but efforts to detonate it, by means of a booster explosive, have resulted in a maximum rate of decomposition approximately equal to 400 meters per second.

f. Stability and Hygroscopicity

Black powder is very stable in the absence of moisture. Its ingredients are non-reactive with each other even when damp or wet. However, black powder when in contact with either copper, brass or steel and in the presence of moisture will cause a reaction between the metals and the black powder ingredients. This reaction forms side compounds that eventually produce instability.

Heating black powder above 70°C causes a rapid increase in the volatility of the sulfur and results in a change of composition and uniformity.

Black powder is undesirably hygroscopic because of the porosity of charcoal or bituminous materials and the nitrates.

When used for military purposes black powder is required to contain less than 0.7 per cent moisture and is usually dried so that it contains only 0.2 to 0.3 per cent moisture before loading.

4. Uses

Although black powder has been replaced by single-base, double-base and composite propellants, it is used in several grades in the following categories:

a. Primers and igniters for artillery shells

b. Delay elements in fuzes

c. Expelling charges for base-ejection smoke shells, illuminating shells and pyrotechnics

d. Saluting and blank-fire charges

e. Smoke-puff and spotting charges for practice ammunition

f. Bursters in incendiary ammunition

g. Burster charges for explosive shells

h. Safety fuzes

i. Quick-match

j. Spotting charges for practice bombs and shells and sub-caliber shells

k. Time-train rings in time and combination fuzes

l. Igniters in jet propulsion units

m. Blasting operations.

C. Squib Compositions

Military squibs or low-explosive squibs function from the heat developed by an electrical-resistance

wire. This heat may ignite a charge of black powder made from potassium nitrate, sodium nitrate or an ignition composition containing:

| | Per cent |
|---|---|
| Potassium Chlorate | 58 |
| Diazodinitrophenol | 40 |
| Nitrostarch | 2 |

Also frequently used is the following matchhead composition:

| | |
|---|---|
| Potassium Chlorate | 30 |
| Antimony Sulfide | 20 |
| Dextrin | 50 |

These compositions may be used to ignite the main charge of black powder.

## IV. SOLID PROPELLANTS

### A. General

Solid propellants contain the necessary chemical ingredients for combustion or the conversion of their chemical energy to useful kinetic energy. One of the ingredients is a fuel and the other material is called an "oxidizer." By means of combustion, heat energy is released which is eventually converted to kinetic energy of the reaction products. The kinetic energy can be controlled to propel a solid body, a projectile, rocket or bullet.

A solid propellant used to effect propulsion must be composed in a manner that will be compatible with the requirements of the missile system. In evaluating and comparing solid propellant properties, the following are considered important and desirable:

1. A high release of chemical energy
2. A low molecular weight of the combustion products
3. Should be stable and should not deteriorate chemically or physically during storage for long periods of time
4. High density
5. Should be unaffected by atmospheric conditions
6. Should not be subject to accidental ignition
7. Should have high physical strength properties
8. Should have a small coefficient of thermal expansion
9. Should be chemically inert during storage and operation and should not require special materials for chamber or nozzle construction
10. Should lend itself readily to production and have desirable fabrication properties
11. The performance properties and fabrication technique should be relatively insensitive to impurities
12. A low temperature sensitivity is desirable
13. The exhaust gas should be smokeless
14. Should lend itself readily to bonding to the

metal parts, to the application of inhibitors, to different production techniques and should be amenable to the use of a simple igniter

15. The exhaust should be non-luminous and non-toxic

16. The method of preparation should be simple

17. The conductivity and specific heat should be such as to control heat transfer of the grain

18. The propellant grain should be opaque to radiation

19. The propellant should resist erosion.

Solid propellants are usually considered to undergo a change by burning only, however, they can also be detonated. The ease of detonation depends upon the physical state of the propellant.

B. Classification

Solid propellants are classified by their composition into three (3) general types as follows:

1. <u>Single-base</u> Propellant or <u>Monopropellant</u>

A single-base propellant or monopropellant is a single, <u>stable</u> chemical compound that does not require an added oxidizer but decomposes to furnish its own oxidizer and reducing agent. At elevated temperatures and pressures these propellants decompose and convert the heat of decomposition into kinetic energy.

Many monopropellants have been developed but the pure monopropellants have limited use because of poor stability. Nitrocellulose, a nitrated raw cotton, is the most widely used monopropellant but possesses poor stability. At normal temperatures pure nitrocellulose decomposes slowly and in time decomposition is complete. However, with the use of chemical additives, nitrocellulose is quite useful as a single-base or monopropellant.

Other single-base propellants or monopropellants (liquid and solid) being used are: ammonium nitrate, mercury fulminate, pyro-nitrocellulose (pure), nitroglycerin, nitromannite, picric acid, nitrocellulose powders, flashless-non-hygroscopic (FNH) powders, non-hygroscopic (NH) powders and ethyl cellulose (EC) powders.

2. Double-base or Homogeneous Propellant

A double-base or homogeneous propellant is a single composition or colloidal phase of oxidizer and reducing agent. This propellant class is often called colloidal powder.

Many of the pure monopropellants have been blended or compounded into double-base or homogeneous propellants. This is true of nitrocellulose and nitroglycerin blending. Stabilizers, plasticizers and other organic or inorganic additives are consolidated to improve the properties of double-base propellants.

Typical double-base propellants now in use are the cordite series propellants, ballistite, "ball propellants," double-base cast propellants, mortar powders, small arms, cannon and rocket propellants.

3. Composite or Heterogeneous Propellants

Composite or heterogeneous propellants include compositions in which the oxidizer and reducing agent are separate entities. A composite propellant may be a mechanical mixture of finely powdered materials with a binding agent. Gunpowder is a composite propellant with potassium nitrate as the oxidizer. Carbon is the reducing agent and sulfur is a combination of binder and reducing agent. The GALCIT propellant contains an asphalt-oil or asphalt-resin as a combination fuel binder. The use of light metal perchlorates and nitrates, ammonium perchlorate and nitrate, smokeless propellants and lithium perchlorate has indicated high performance composite propellants.

More than one million organic compounds are known to be used as reducing agents indicating an untold number of the possible composite propellants that may be produced. Also, with the advances in the fields of plastics, resins, polymers and related fuel binders, the possibilities of numerous new composite propellants are astounding.

It is anticipated that a suitable, pure monopropellant may eventually be synthesized, however, it appears that a more versatile composite propellant will result by compounding an oxidizer and a reducing agent to produce the desired ballistic and physical properties for the ideal propellant.

C. Uses

Single-base or monopropellant compositions are used

as cannon and small arms powder, propellants, grenades, blasting powders, dynamites and combination mixtures for double-base propellants. Double-base or homogeneous propellants can also be used as cannon or small arms propellants, mortars, rockets and jet propulsion units. The composite compositions are used in rocket assemblies and jet propulsion units. The choice of a propellant for a specific use is determined by ballistic and physical requirements, rather than on the basis of composition. However, a given composition may be suitable for use in several different applications.

D. Form

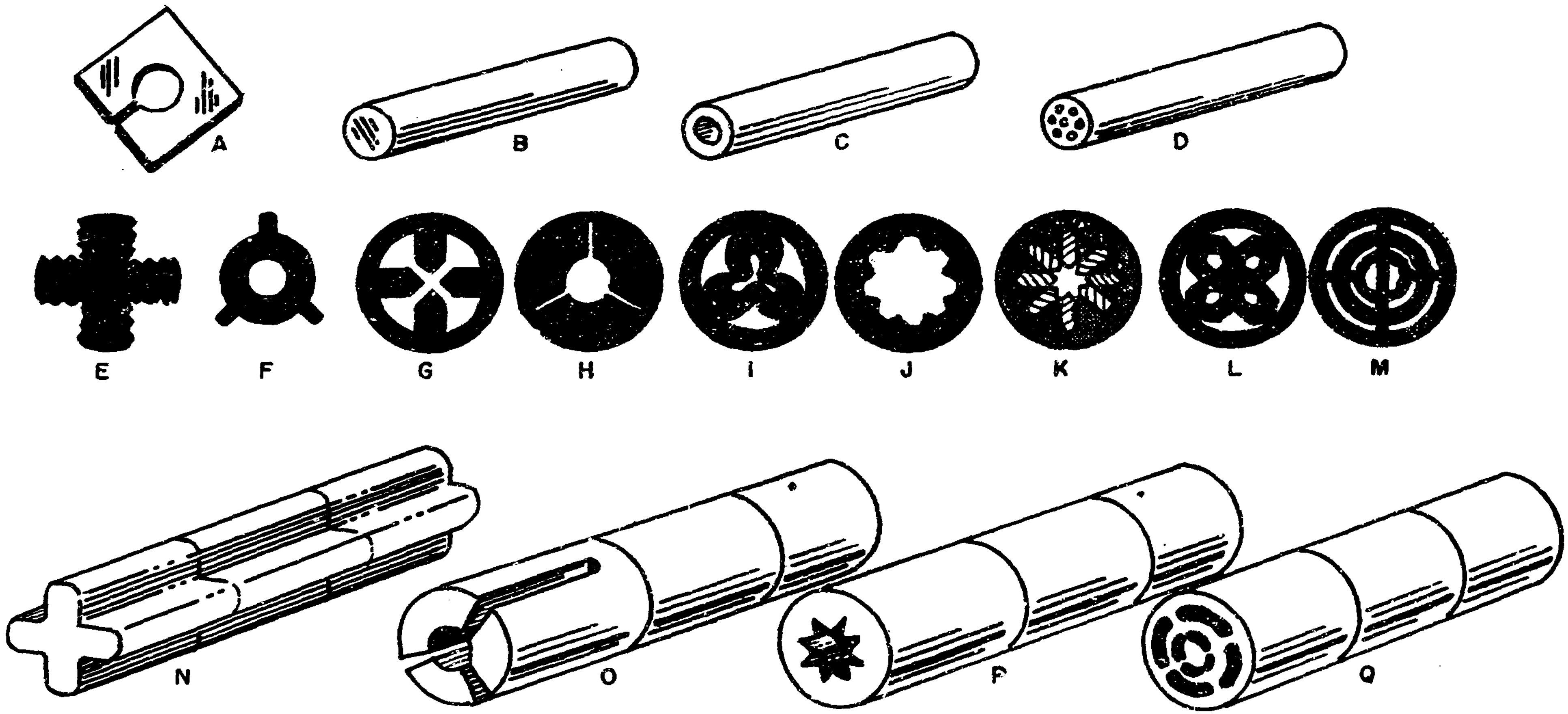
Solid propellants are manufactured in the form of flakes, balls, sheets, cords or perforated cylindrical grains. The cords and cylindrical grains are produced in various diameters and lengths and may be extruded, molded or cast. Numerous shapes are used to obtain various burning surfaces. The burning surface area is determined by grain configurations that may include either perforations (single or multiple), or star, rosette, cruciform and slotted designs. Figure 2-2 illustrates several of the various forms and shapes of solid propellants.

E. Burning Action

Unconfined propellants burn relatively slow and smooth. When confined the burning rate increases greatly with temperature and pressure. The burning of each confined propellant composition exerts a build-up pressure and each combustion chamber possesses a pressure limit less than the chamber-eruption pressure. Therefore, the burning surface of any solid propellant within an engine must be controlled in order that the permissible chamber pressure will not be exceeded. At any given pressure the rate of burning is proportionate to the propellant surface free to burn and the area of the throat of the engine nozzle. For this reason solid propellant grains are manufactured into definite sizes, shapes and configurations.

Any form of grain that presents a decreasing surface area during combustion is termed a <u>degressive burning</u> grain. Grains that present an increasing surface area as combustion progresses are termed <u>progressive burning</u> grains. Since tubular or single perforated grains show <u>only</u> slight change of surface area during combustion, they are usually referred to as <u>neutral burning</u> grains. Figure 2-3 illustrates the comparative burning rates and types of burning of different shaped propellant grains.

Cord and strip forms of propellant present degressive burning because the surface of the grain decreases during combustion.




A. SHEET
B. CORD
C. SINGLE PERFORATED
D. MULTI-PERFORATED
E. SERRATED CRUCIFORM

F. JP INCREMENT
G. JATO CROSS
H. SLOTTED
I. SPADE-MULTI-PERFORATED
J. 8-POINT FLAT STAR

K. DUAL PROPELLANT
L. MULTI-PERFORATED (SPECIAL)
M. MULTI-PERFORATED (SPECIAL)
N. CRUCIFORM
O. SLOTTED END (IGNITER), SINGLE PERFORATED

P. STAR PERFORATED
Q. MULTI-PERFORATED-(SPECIAL)

FIG. 2-2: SHAPES AND FORMS OF PROPELLANT GRAINS

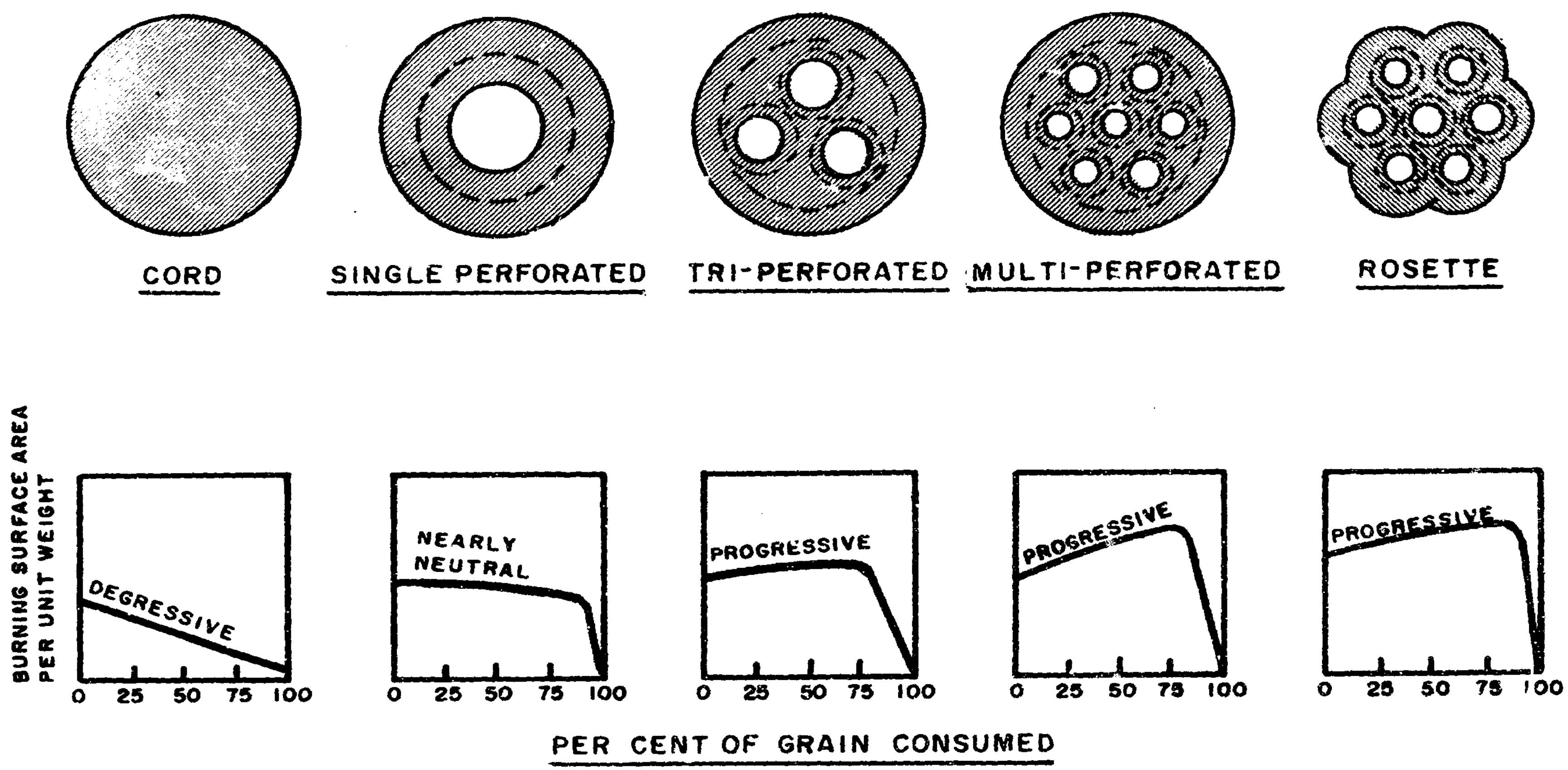



FIG. 2-3: COMPARATIVE BURNING RATES OF DIFFERENT SHAPED PROPELLANT GRAINS

When multi-perforated grains burn the total surface area increases. This is caused by simultaneous inside and outside burning. As these grains burn, incomplete consumption of the unburned propellant remains. This unburned propellant is called slivers and may be consumed by afterburning in the bore of the weapon or the combustion chamber of a rocket.

Single-perforated propellant grains exhibit neutral burning. As the grain burns the outer surface decreases and the inner surface increases. The result of the two actions causes the total surface to remain approximately the same in area.

F. Compositions

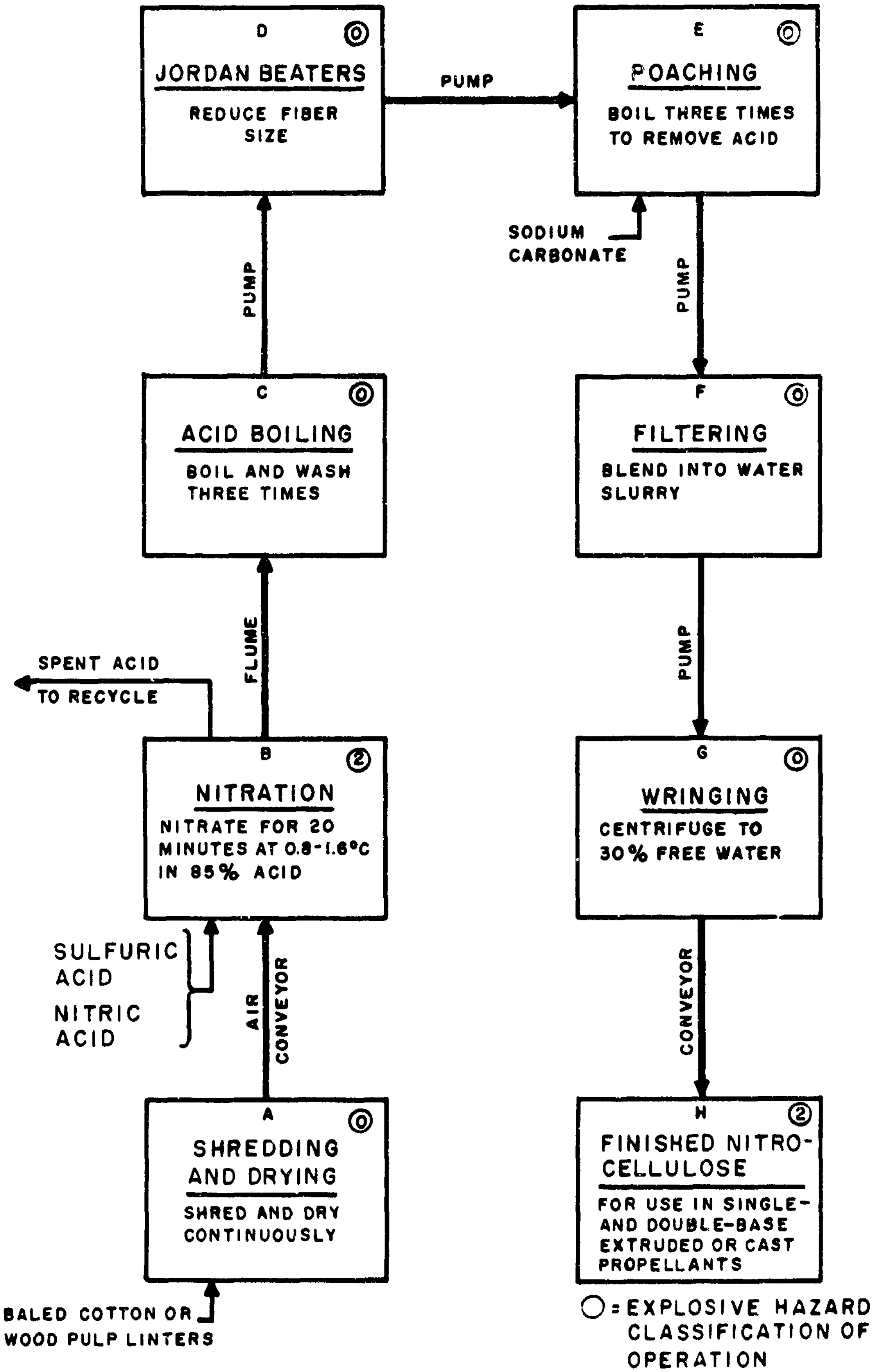
1. Single-base Compositions

The majority of single-base compositions contain a high percentage of nitrocellulose as the main ingredient. Flow Sheet No. 1 describes the manufacture of nitrocellulose. In addition to a stabilizer, single-base compositions may contain inorganic nitrates, nitro-compounds and non-explosive materials as metallic salts, metals, carbohydrates and dyes.

The nitrocellulose is gelatinized by means of solvent mixtures (ether-alcohol, alcohol-benzene or acetone-alcohol). A stabilizer (diphenylamine, 2-dinitrodiphenylamine, ethyl centralite, etc.) is consolidated into the gelatinized nitrocellulose and the mixture can be extruded into cord, single-perforated or multi-perforated form. The additives, such as the non-organic compounds, are incorporated before extrusion and render the propellants flashless, non-hygroscopic and/or smokeless.

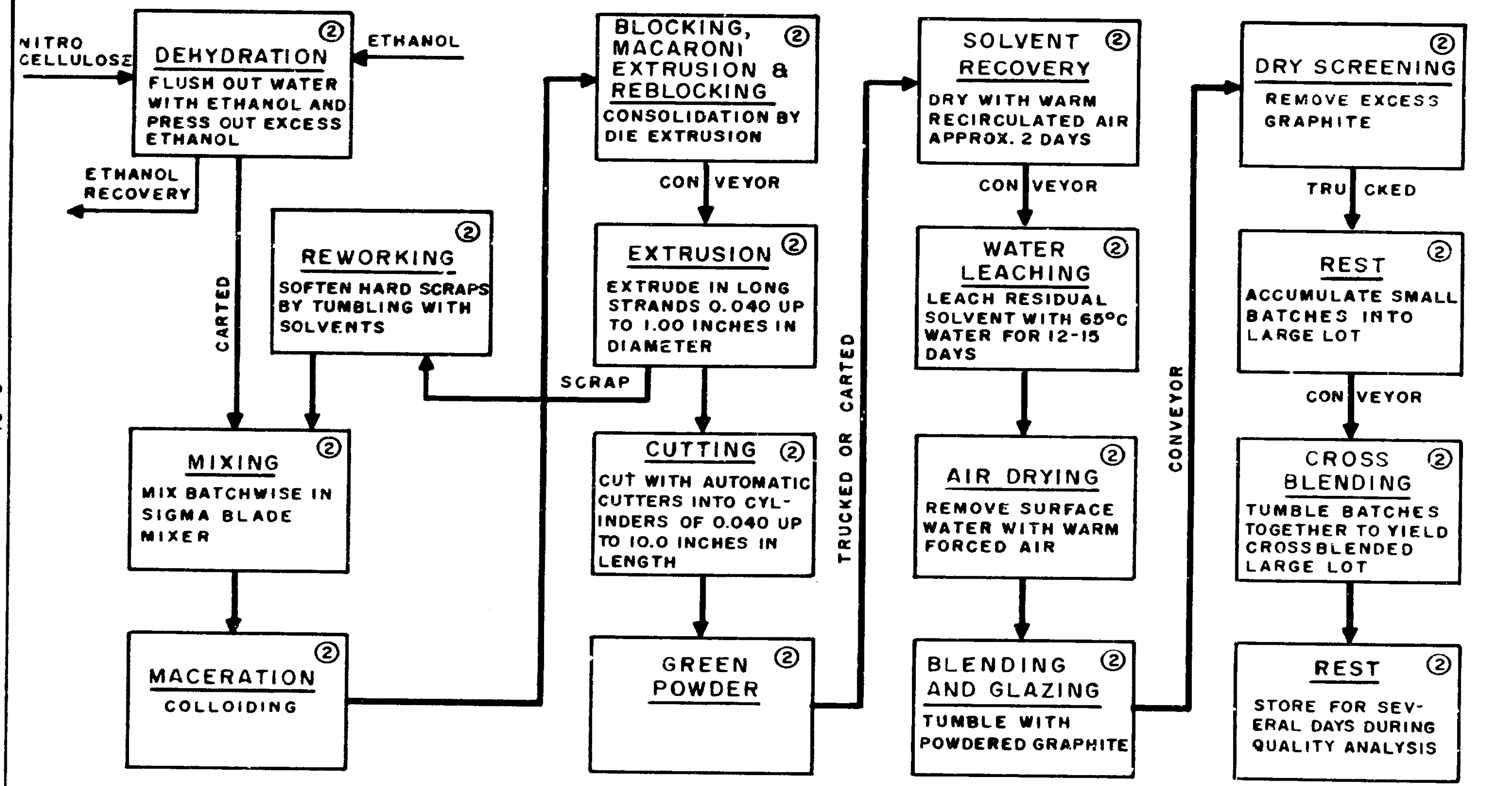
In the single-base compositions, the organic materials dinitrotoluene and trinitrotoluene act as gelatinizing and moisture-proofing agents and contribute some ballistic potential. Dibutylphthalate and triacetin are also gelatinizing and moisture-proofing agents but contribute no ballistic potential. However, they aid in rendering the composition flashless. Potassium sulfate, tin and cryolite serve as flash-reducing agents and the diphenylamines and ethyl centralite act as stabilizers. Tin also acts as an anti-fouling and a de-coppering agent.

Most single-base propellants are manufactured in a sequence of processes that involves ten (10) or more operations (see Flow Sheet No. 2). The wet




FLOW SHEET NO. 1

MANUFACTURE OF NITROCELLULOSE




FLOW SHEET NO. 2 - FOR SINGLE-BASE PROPELLANTS AND SINGLE-BASE CASTING POWDER FOR CASTING DOUBLE-BASE PROPELLANTS

○ = EXPLOSIVE HAZARD CLASSIFICATION OF OPERATION - ②, ⑨, ⑩ OR ⓪ (NON-EXPLOSIVE)

nitrocellulose is dehydrated after the moisture content has been reduced by mechanical wringing (spin type) to approximately twenty-eight (28) per cent. Further dehydration is accomplished by compressing (hydraulic block-press) the nitrocellulose into a block at low pressure (1200-1700 psi) eliminating most of the water by flowing ninety-five (95) per cent ethanol through the block under 3500 psi pressure. A block containing approximately twenty-five (25) pounds of dry nitrocellulose and about eight (8) pounds of ninety (90) per cent ethanol is obtained. The block is broken into small lumps by means of a rotating drum containing iron prongs and a screen. The broken nitrocellulose is then transferred to a water-cooled mixer of the dough-mixer type. During this operation ether equal to approximately two-thirds (2/3) of the weight of dry nitrocellulose is added. Any plasticizing agents and stabilizers to be included in the composition are dissolved in or mixed with the ether prior to its addition to the nitrocellulose. After addition of the ether, materials such as potassium sulfate are added. Mixing of the ingredients is continued for about one (1) hour. This produces a partial colloidal solution that resembles dry oatmeal in appearance. This solution is pressed at approximately 3000 psi, to form a block, thereby rapidly increasing the degree of colloiding. The colloiding effect is further increased and uniformity of the mixture is improved by subjecting it to a pressure of about 3500 psi in a macaroni press. The material is squeezed through a series of screens and perforated plates and emerges in a form resembling that of macaroni. This macaroni block is placed in a graining press and extruded through an accurately designed die attached to a hydraulic ram. The pressure is between 2500 and 3900 psi. The material emerges as a cord with one (1) or more cylindrical perforations. By means of a cutting machine the cord is cut into pieces of predetermined length. Removal of the volatile solvent with shrinkage of the grains to their final dimensions is accomplished in three (3) operations. In the solvent recovery operation the propellant is placed in a large tank and warm air or other gases are passed through the mass. With careful control, to prevent surface-hardening, the temperature of the air is gradually increased to not more than 65°C. The solvent recovery operations require from 2 to 14 days, depending upon the size of the grain. This process reduces the solvent content to approximately six (6) per cent. The "water-dry" operation consists of placing the partially dried propellant

in water at approximately 25°C and gradually increasing the temperature to a maximum of 55°C. After several days (2 to 6), the residual solvent is reduced to 0.3 to 5.0 per cent depending upon the grain size. The propellant is air dried to remove surface moisture and screened to remove dust and grain clusters. The final operation before packing is to blend all the powder in a lot, which may vary from 50,000 to 500,000 pounds depending on the type of powder. This is accomplished by transferring the powder from one bin to another by gravity flow, the bins being conical in shape. This blending improves uniformity of the lot with respect to average composition and external moisture content. Glazing with graphite can be accomplished during the screening procedure. The graphite glaze is added to facilitite the uniform action of automatic loading machines and to avoid the development of large static electrical charges during blending and loading.

Typical formulations of single-base propellants are listed in Table 2-2.

2. Double-base Compositions

Double-base propellants usually contain nitrocellulose and nitroglycerin as the major ingredients. In some compositions diglycol dinitrate or pentaerythritol trinitrate are used as a combined fuel-oxidizer in place of nitroglycerin. These major ingredients are accompanied by one or more inorganic or organic compounds that insure stability, reduce flash or flame temperature (or both) and improve ignitability. Other ingredients are added to aid processing, curing and the physical and ballistic properties of the propellant.

The nitrocellulose used in double-base propellants usually contains 12.6 per cent nitrogen but the nitrogen percentage may fall within a range of 12.2 to 13.25 per cent. The supply of glycerin used in the manufacture of nitroglycerin was limited for many years, but recent developments in production of synthetic glycerin have greatly increased the use of double-base propellants in the production of rocket and JATO solid propellants.

A double-base propellant may contain 39-69 per cent nitrocellulose, 19-54 per cent nitroglycerin, 1-29 per cent plasticizer, 1-3 per cent stabilizer, 1 per cent processing aids and 0.0-1.5 per cent solvent.

Generally, double-base propellants are easily

TABLE 2-2 TYPICAL FORMULATIONS OF SINGLE-BASE PROPELLANTS

| Ingredients | Percentage by weight | | | | | | |
|---|---|---|---|---|---|---|---|
| Nitrocellulose | | | | | | | |
| 1. 12.60% $N_2$ | --- | 79 | --- | --- | --- | --- | --- |
| 2. 13.15% $N_2$ | 84.2 | --- | --- | 86.1 | 98.0 | 97.7 | 89.1 |
| 3. 13.25% $N_2$ | --- | --- | 76 | --- | --- | --- | --- |
| Dinitro-toluene | 9.9 | --- | 23.0 | 9.9 | --- | (x) | 7.9 |
| Trinitro-toluene | --- | 15.0 | --- | --- | --- | --- | --- |
| Dibutyl-phthalate | 4.9 | --- | --- | 3.0 | --- | --- | 2.0 |
| Triacetin | --- | 5.0 | --- | --- | --- | --- | --- |
| Potassium Sulfate | --- | --- | --- | --- | 1.0 | 0.75 | --- |
| Tin | --- | --- | --- | --- | --- | 0.75 | --- |
| Diphenyl-amine | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.8 | 1.0 |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

(x) Coating

ignited, have high burning rates, high-flame temperature and high force or propulsion.

The solvent process used for manufacturing double-base propellants is very similar to that of single-base propellants. Flow Sheets No. 3 and 4 are typical of the processes used in manufacturing extruded double-base propellants.

The solvent used is a mixture of ethanol and acetone and the solvent recovery procedure is omitted because of the hazard involved in recovering solvents containing nitroglycerin. The nitrocellulose undergoes the same processing for both single-base and double-base propellants and is blocked and shredded by the same methods. After breaking up the nitrocotton, nitroglycerin is added slowly. Then, consolidation of carbon black, oxidizer, stabilizer, plasticizer, press lubricant, solvent and other additives is accomplished in a macerator-type mixer. The colloidal mass is then blocked, extruded and dry-cured. In the case of cast double-base propellants the base-grain is processed as single-base propellants. The base-grain propellant is placed in an acetate-restrictor mold. Then the nitroglycerin-plasticizer-stabilizer casting liquid permeates the base-grain by means of vacuum. Drying or curing is accomplished by the high-heat plateau method.

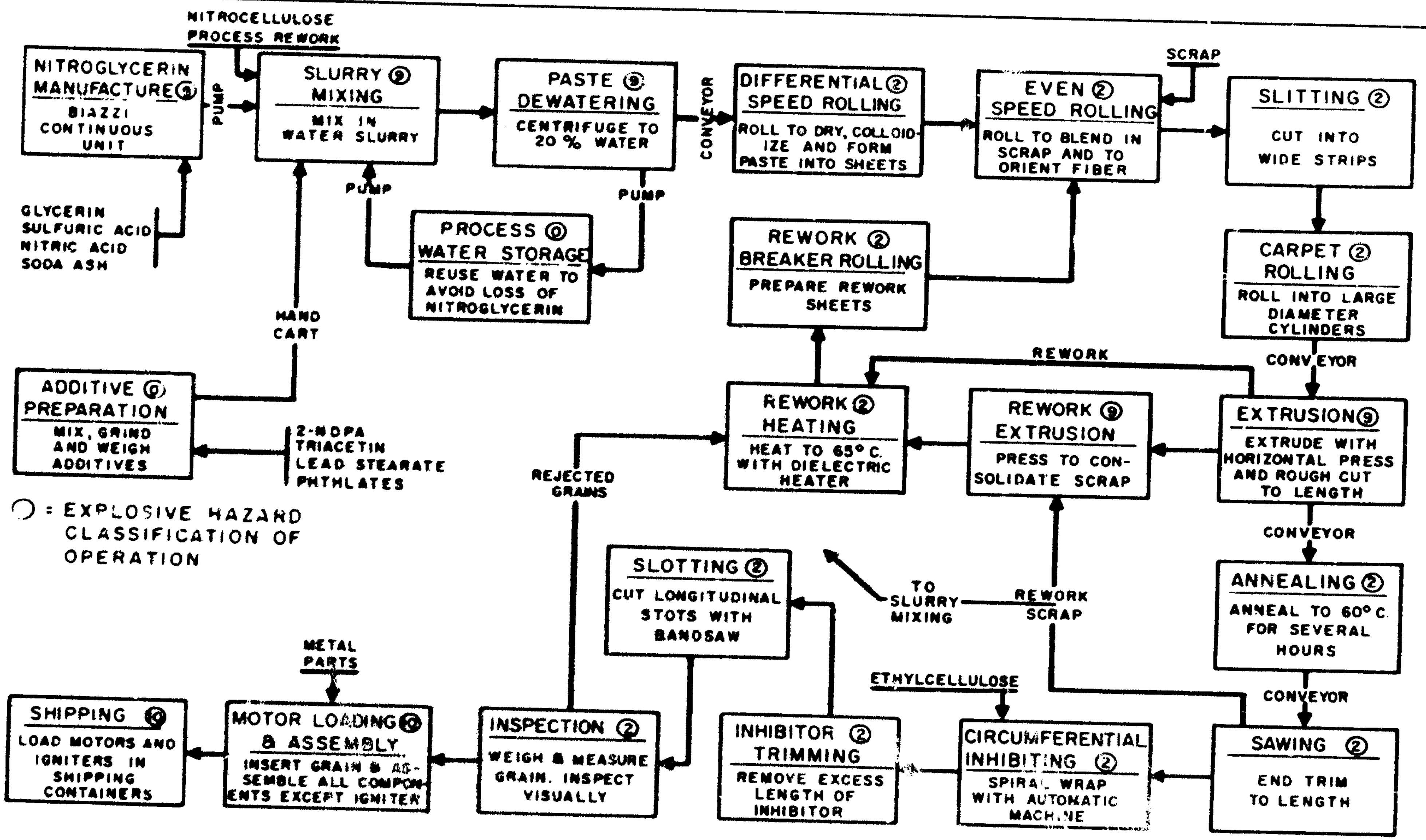
Another double-base propellant manufacturing method is the non-solvent process. This method is used when the nitroglycerin and any other colloiding agent constitues approximately forty (40) per cent of the composition.

Due to their hazardous nature, double-base materials are handled under closely controlled conditions. The individual materials are almost as hazardous as the combined oxidizer and fuel of the compounded propellant.

Some of the typical double-base propellant formulations are shown in Table 2-3.

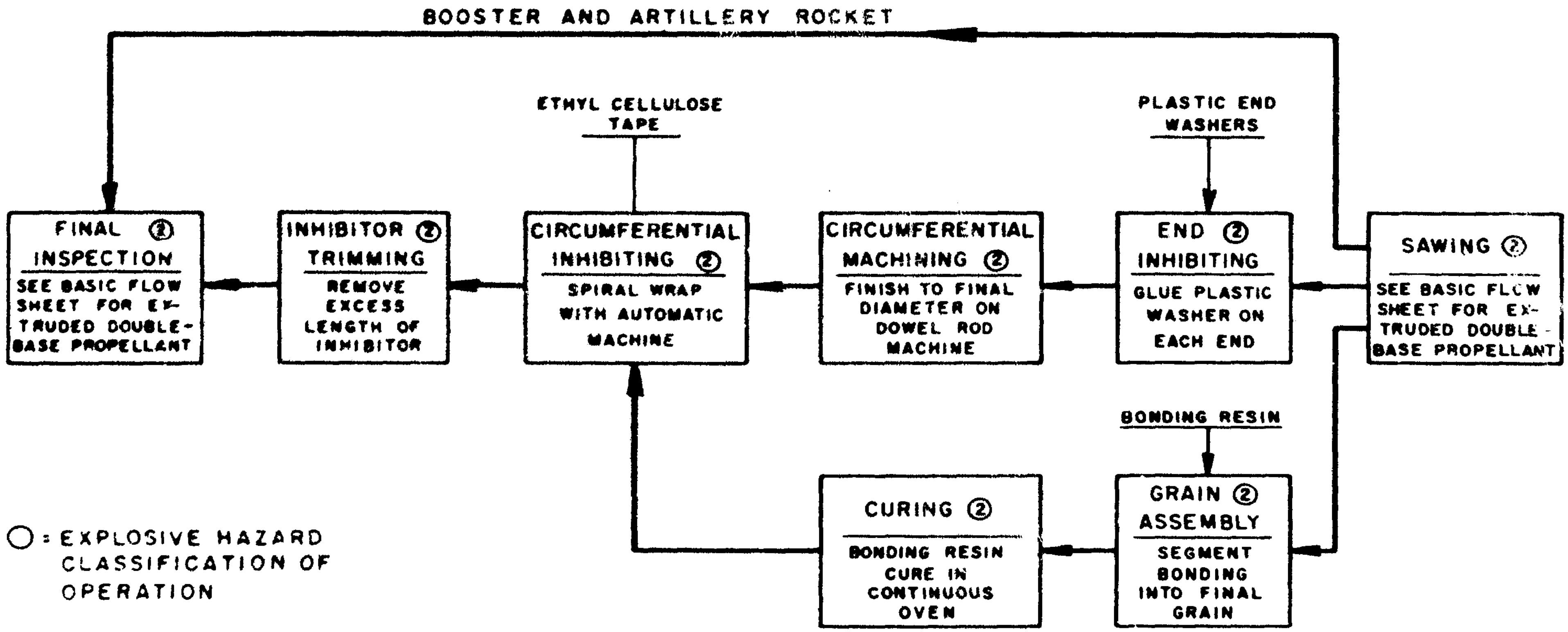
3. Composite Compositions

Difficulties encountered in the manufacturing of double-base propellants for rockets and JATOS led to the development of the composite propellants. The composite propellants are solid, uncolloided, heterogeneous, combustible mixtures consisting of an organic fuel, an inorganic oxidizing agent and an organic binding agent. Composite propellants




FLOW SHEET NO. 3 - EXTRUDED DOUBLE-BASE PROPELLANTS

SEE ALTERNATE FINISHING OPERATIONS




○ = EXPLOSIVE HAZARD CLASSIFICATION OF OPERATION

FLOW SHEET NO. 4 - ALTERNATE FINISHING OPERATIONS FOR EXTRUDED DOUBLE-BASE PROPELLANTS

<table>
<tr><th>INGREDIENTS</th><th colspan="8">Percentage (by weight)</th></tr>
<tr><td>Nitrocellulose</td><td>55-73</td><td>52-82</td><td>19-22</td><td>53</td><td>51-61</td><td>55-62</td><td>51</td><td>45-50</td></tr>
<tr><td>Nitroglycerin</td><td>20-30</td><td>15-43</td><td>19-21</td><td></td><td>20-30</td><td>18-28</td><td>35</td><td>30-40</td></tr>
<tr><td>Nitroguanidine</td><td></td><td></td><td>54-60</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Di Glycol Dinitrate</td><td></td><td></td><td></td><td>35</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Dinitrotoluene</td><td rowspan="8">7-15</td><td rowspan="8">3-5</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Ethyl Centralite</td><td></td><td></td><td>1.2</td><td></td><td>1.5</td><td></td></tr>
<tr><td>Potassium Sulfate</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Carbon Black (added)</td><td></td><td></td><td></td><td></td><td>0.5</td><td></td></tr>
<tr><td>Lead Stearate</td><td></td><td></td><td>3-4</td><td></td><td></td><td></td></tr>
<tr><td>Triacetin</td><td></td><td></td><td>8-18</td><td>1-12</td><td></td><td>2-12</td></tr>
<tr><td>Other Additives</td><td>1-5</td><td>12</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Lead Salicylate</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>2-3</td></tr>
<tr><td>Di-N-Propyl Adipate</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>3-5</td></tr>
<tr><td>2-NDPA</td><td></td><td></td><td></td><td></td><td></td><td>1-2</td><td>2</td><td>2</td></tr>
<tr><td>Dimethyl Phthalate</td><td></td><td></td><td></td><td></td><td></td><td>2-9</td><td>10</td><td></td></tr>
<tr><td>Series Identification</td><td>T-Series</td><td>M-Series</td><td>Triple Base</td><td>Special Cast</td><td>Cast Double-Base</td><td>Cast Double-Base</td><td>N-Series</td><td>X-Series</td></tr>
</table>

TABLE 2-3 - TYPICAL DOUBLE-BASE COMPOSITIONS

contain neither nitrocellulose nor nitroglycerin. These composite propellants can be manufactured by a simple mixing operation and molded into a grain of a desired form by compressing or casting. These grains may be coated on the surface with cellulose acetate or other inhibitor materials to aid in controlling the grain burning action. Flow Sheets No. 5, 6 and 7 present typical manufacturing data for the production of composite propellant compositions. Earlier composite propellants tended to become brittle and crack at low temperatures. However, recent development of binding agents less affected by low temperatures has greatly expanded the use of this type propellant.

The solid-oxidizing agents that have been used in the solid-composite propellants include ammonium chlorate, nitrate, perchlorate and picrate; lithium nitrate and perchlorate; potassium chlorate, perchlorate and nitrate; sodium chlorate, perchlorate and nitrate.

The use of chlorates of ammonia, sodium and potassium has decreased because of their low oxygen content, white-smoke exhaust and hygroscopicity. Ammonium picrate was previously used in composite propellants but due to its toxicity, heat and shock sensitivity, it is now seldom used as an oxidizing agent. Potassium perchlorate is being replaced by the ammonium salts. Sodium perchlorate is deliquescent to a great extent, therefore, it is not being used.

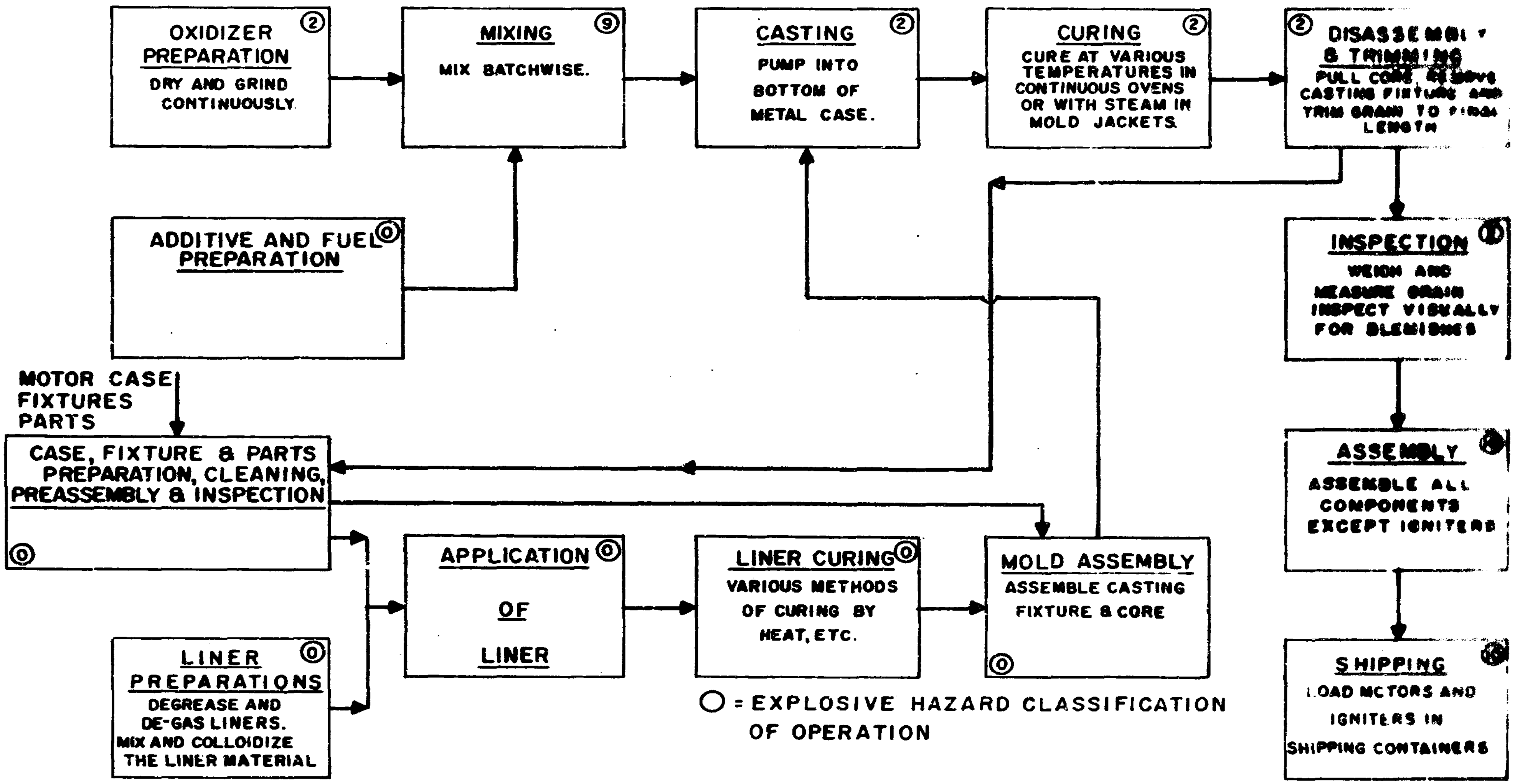
Lithium nitrate and lithium perchlorate are commercially produced and have been added to the increasing list of the better solid-oxidizing agents.

Ammonium nitrate and ammonium perchlorate are the solid-oxidizing agents now being used due to low cost, low-combustion temperature and a less smokeless flame when ignited.

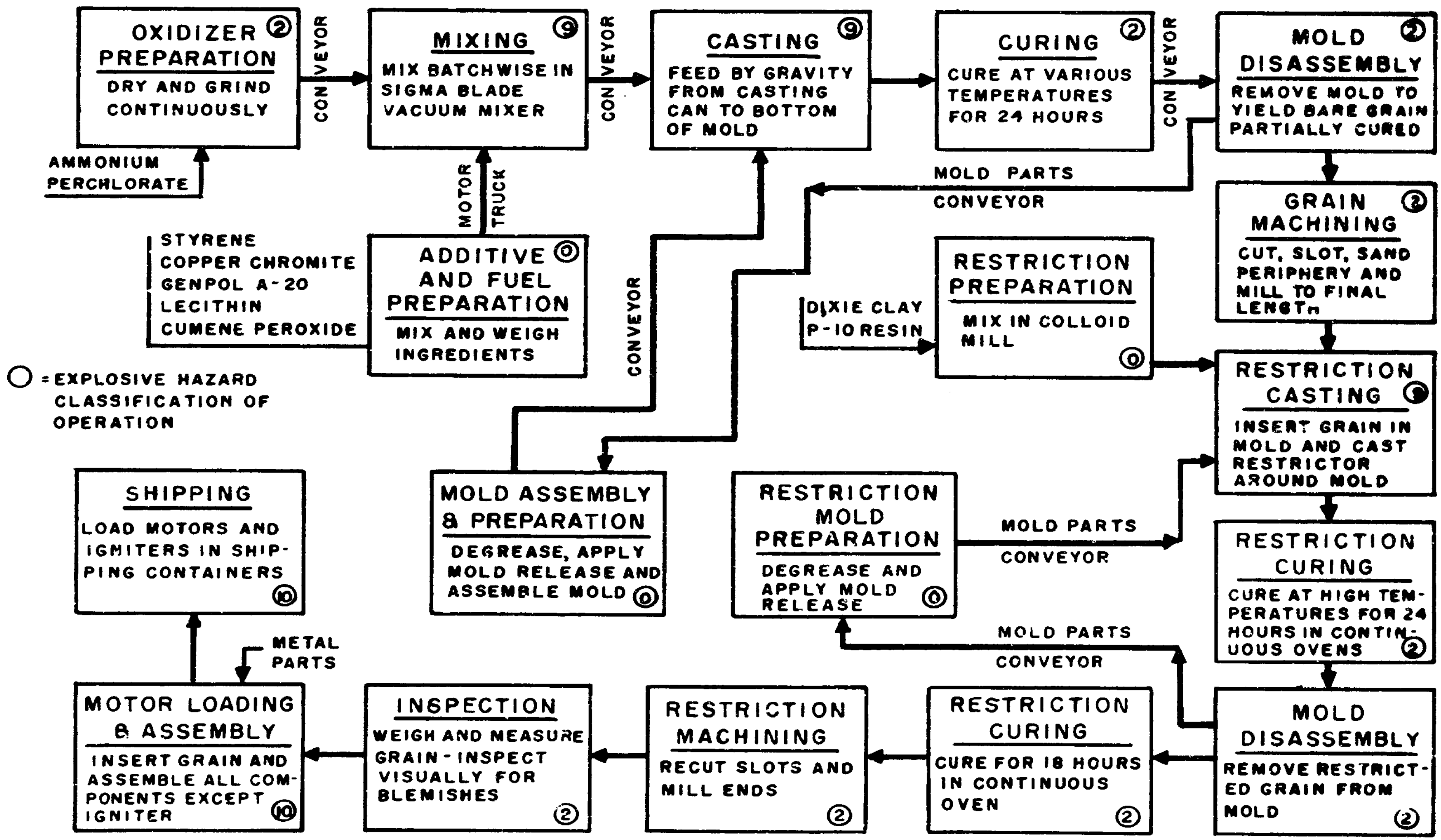
The fuel binders used for composite propellants include resins, plastics and organic binders. The casting resins include epoxies, epoxy-polysulfides, phenolics, polyesters, polyethylenes, polysulfides, polyurethanes and polyvinyl chloride plastics.

Table 2-4 indicates a typical basic composition of a solid-composite propellant.

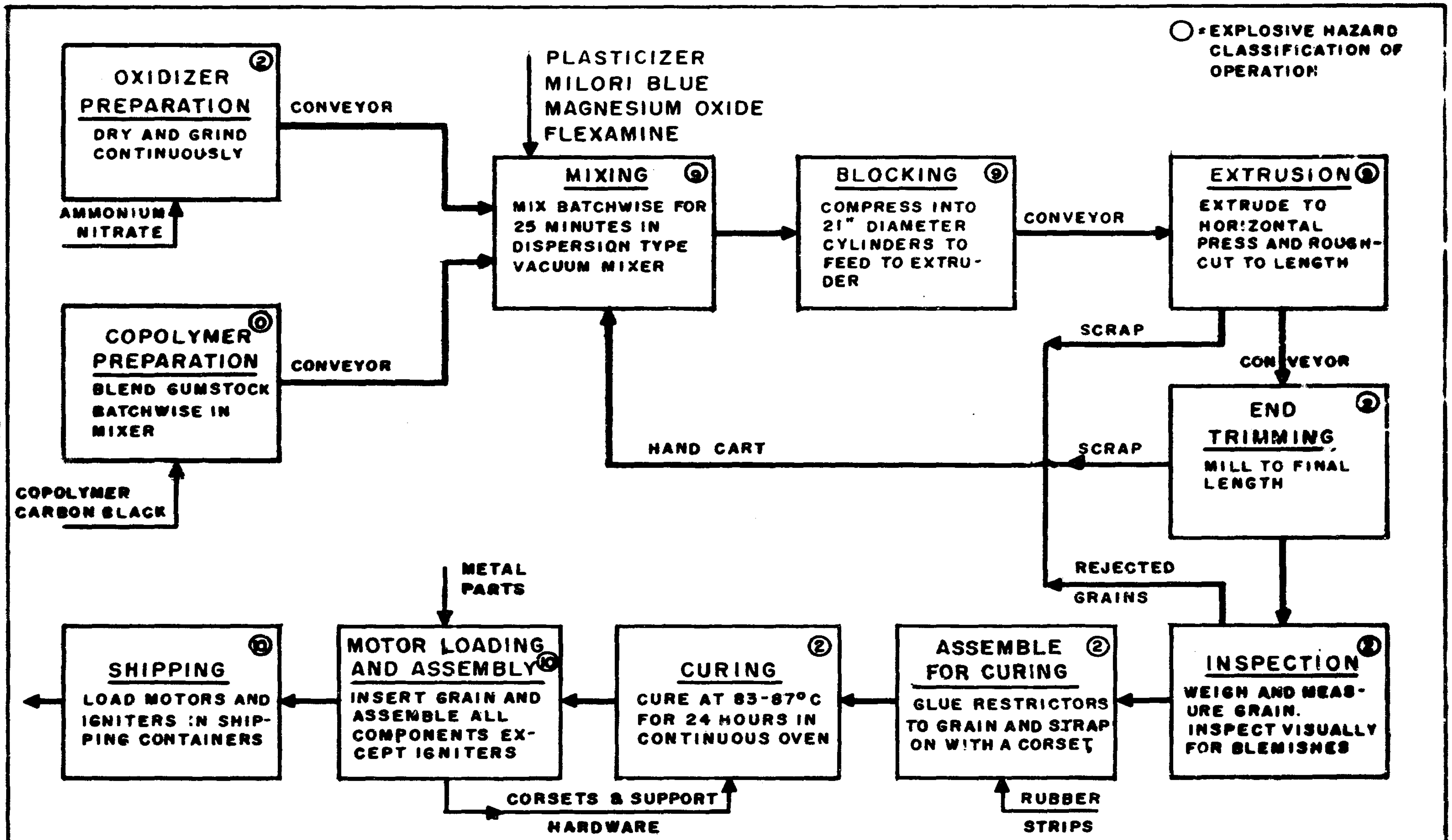
The more common catalytic agents used to control the burning rate in composite propellants are ferric oxide, ammonium dichromate, manganese dioxide, Milori Blue, Monastrol Blue and boron salts.




FLOW SHEET NO.5 TYPICAL FLOW SHEET FOR COMPOSITE PROPELLANTS
POLYSULFIDE/PERCHLORATE, POLYURETHANE/PERCHLORATE AND PVC PLASTISOL/PERCHLORATE TYPES




FLOW SHEET NO. 6 - POLYESTER/PERCHLORATE PROPELLANTS




FLOW SHEET NO. 7 - BUTADIENE-MVP RUBBER-NITRATE PROPELLANTS

TABLE 2-4 - TYPICAL BASIC COMPOSITION OF SOLID COMPOSITE PROPELLANTS

| Ingredient | Percentage by Weight | |
|---|---|---|
| | High Impulse Propellant | Low Impulse Propellant |
| Oxidizer | 81.0 | 70.0 |
| Metal (powdered) | 2.0 | ---- |
| Fuel binder | 10.0 | 23.0 |
| Catalyst | 2.3 | 2.3 |
| Polymer reinforcement | 2.0 | 2.0 |
| Anti-oxidant | 0.3 | 0.3 |
| Curing agent | 0.4 | 0.4 |
| Plasticizer | 2.0 | 2.0 |

A few burning-rate modifiers and suppressors are salicylates of lead and copper; oxides of lead, copper and iron; lead resorcylate; resorcinol; melamine; cellulose acetate and magnesium oxide.

Coolants and anti-oxidants include Flexamine, Lecithin and Cyanoguanidine.

Curing accelerators, catalysts or agents used in composite propellants are para-quinone dioxime (GMF), tertiary-butyl and cumene hydroperoxide, sulfur, flowers-of-sulfur, benzyl mercaptan, xylyl mercaptan, para-xylene hexachloride and diphenylguanidine.

The stabilizers used in composite propellants include phthalates, adipates, sebacates, formals, styrenes, acrylates and a few acetate derivatives.

## G. Ingredients

The ingredients used in the various solid propellants are categorized in accordance to their function. Table 2-5 is not complete but contains representative compounds used in the manufacture of single-base, double-base and composite-solid propellants. Also, several trade-name compounds are included in this list since the exact composition is not known to the authors.

## H. Other Propellant Classifications

Other classifications of solid propellants include solvent or solventless propellants and restricted or unrestricted propellants.

The solvent propellants include the single and double-base propellants processed with alcohol, ether, acetone and other solvents used to colloidize or consolidate the ingredients.

The solventless propellants include the single-base, double-base or composite propellants that are compounded without use of solvents such as alcohol, ether and acetone. These propellants are formed by compressing, rolling, casting or binding.

Restricted and unrestricted propellants relate to the grain configuration, the encasement and the rate of burning. The restricted propellant grain is a solid bonded-encased grain and burns similar to a cigarette.

TABLE 2-5 - INGREDIENTS (GROUPED BY PERFORMANCE FUNCTION) USED IN THE MANUFACTURE OF SOLID PROPELLANTS

| ANTI-OXIDANTS, ANTI-RESONANCE AGENTS, COOLANTS AND WETTING AGENTS | |
|---|---|
| Flexamine<br>Lecithin<br>Aluminum<br>Cyanoguanidine<br>British Detergent | Aerosol OT<br>Uversol Cobalt<br>Cobalt Powder<br>Pentaryl A |
| **BURNING RATE CATALYSTS, BURNING RATE MODIFIERS AND BURNING RATE SUPPRESSORS** | |
| Ferric Oxide<br>Ammonium Dichromate<br>Manganese Dioxide<br>Cupric Chromite<br>Boron<br>Calcined Magnesia (MgO)<br>Monastrol Blue<br>Milori Blue<br>Epon 562<br>Magnesium Oxide<br>Cellulose Acetate<br>Melamine<br>Hi-Sil 233 | Carbon Black<br>Cupric Oxide (CuO)<br>Basic Cupric Salicylate<br>Monobasic Cupric Salicylate<br>Ferric Oxide<br>Lead Oxide (PbO and $Pb_3O_4$)<br>Lead Caproate<br>Lead Stearate<br>Lead-B-Resorcylate<br>Monobasic Lead-B-Resorcylate<br>Monobasic Lead Salicylate<br>B-Resorcylic Acid<br>Resorcinol |
| **CURING CATALYST, ACCELERATOR OR AGENT** | |
| Sulfur<br>Flowers of Sulfur<br>Benzyl Mercaptan<br>RPA-3 (Xylyl Mercaptan Concentrated in Hydrocarbon Oil)<br>Lupersol-DDM<br>para-Quinone Dioxime (GMF)<br>Magnesium Oxide | para-Xylene Hydrochloride<br>tert-Butyl Hydroperoxide<br>Cumene Hydroperoxide<br>Barium Perchlorate<br>Diphenylguanidine<br>1,4-bis (trichloromethyl Benzene)<br>BLE-25<br>Zinc Oxide |
| **EXTRUSION OR PROCESSING AIDS AND FILLERS** | |
| Candelilla Wax<br>Graphite<br>Stearic Acid<br>Castor Oil | Lead Stearate<br>Philbac A<br>Carbolac I<br>Nylon Fibers and Tow |

TABLE 2-5 - INGREDIENTS (GROUPED BY PERFORMANCE FUNCTION) USED IN THE MANUFACTURE OF SOLID PROPELLANTS (Continued)

| FUELS AND FUEL BINDERS | |
|---|---|
| Polysulfide Polymers | Methoxyethyl Acrylate |
| Polysulfide, Ethyl-Formal Polymers | Butadiene-rubber Nitrate Polymers |
| Polyvinyl Chloride Resins | Isobutylene-Isoprene mixtures (Butyl rubbers) |
| Polybutylene Glycol Diisocyanate | 2,-Vinyl Pyridene |
| Polyurethanes | Polymer-Resin combinations |
| Epoxide Resins | Butadiene-vinyl Pyridine mixtures |
| Aluminum | Acrylonitrile |
| Asphalts | |
| Methyl Acrylate | |
| Polybutadiene Acrylic Acid | |
| **STABILIZERS FOR FUEL-OXIDIZER MIXTURES AND FUELS OR OXIDIZERS** | |
| Nitrocellulose | Ethylenediamine Dinitrate |
| Nitroglycerin | Diglycol Diacetate |
| Nitroguanidine | Diglycol Dinitrate |
| Pentaerythritol Trinitrate | Methyl-amyl-ketone Peroxide |
| Pentaerythritol | Methyl-ethyl-ketone Peroxide |
| Pentaerythritol Acetate Propionate | |
| **FUEL CURING CATALYSTS AND FUEL VISCOSITY ADDITIVES** | |
| Dicyandiamide | |
| British Detergent | |
| Ethyl Cellulose | |
| **OXIDIZERS** | |
| Ammonium Perchlorate | Barium Nitrate |
| Ammonium Nitrate | Lithium Perchlorate |
| Barium Perchlorate | Potassium Perchlorate |
| **PLASTICIZERS** | |
| Dibasic Lead Phthalate | Cobalt Octoate in Styrene |
| Diethyl Phthalate | Sucrose Octoacetate |
| Dimethyl Phthalate | Triacetate |
| Dioctyl Phthalate | Triacetin |
| Dibutyl Sebacate | Butyl Carbitol Formal |
| Diethyl Sebacate | Di-N-butyltartrate |
| Dimethyl Sebacate | Di-(2-ethyl hexyl Azelate) |
| Dioctyl Sebacate | Lead-2-ethyl Hexoate |
| Dioctyl Adipate | 1,4,Butane Diol |
| Butyl Carbitol Adipate | N, Butyl Acrylate |
| Di-N-Propyl Adipate | Triethylene Glycol-Dinitrate |
| Styrene | Castor Oil |
| Lechithin in Styrene | Philrich 5 (an aromatic oil) |
| | Resins |

**TABLE 2-5 - INGREDIENTS (GROUPED BY PERFORMANCE FUNCTION) USED IN THE MANUFACTURE OF SOLID PROPELLANTS (Continued)**

| STABILIZERS | |
|---|---|
| Barium & Calcium Dodeconate | Diphenylamine |
| Calcium Carbonate | 2-nitro Diphenylamine (2-NDPA) |
| Calcium Hydroxide | Ethyl Centralite |
| Calcium Phosphate | N',N',-diphenyl-diethyl Urea |
| Diallyl Maleate | N-methyl-p-Nitroaniline |
| Diethylene Triamine | tert.-Butyl Catechol |
| Malleic Anhydride | Magnesium Oxide |

The unrestricted propellant grain, depending upon the grain configuration, burns internally, internally-externally or externally. This type of burning is shown in Figure 2-4, Solid Propellant Systems. It illustrates the configuration and the time-thrust curve of several solid propellant systems.

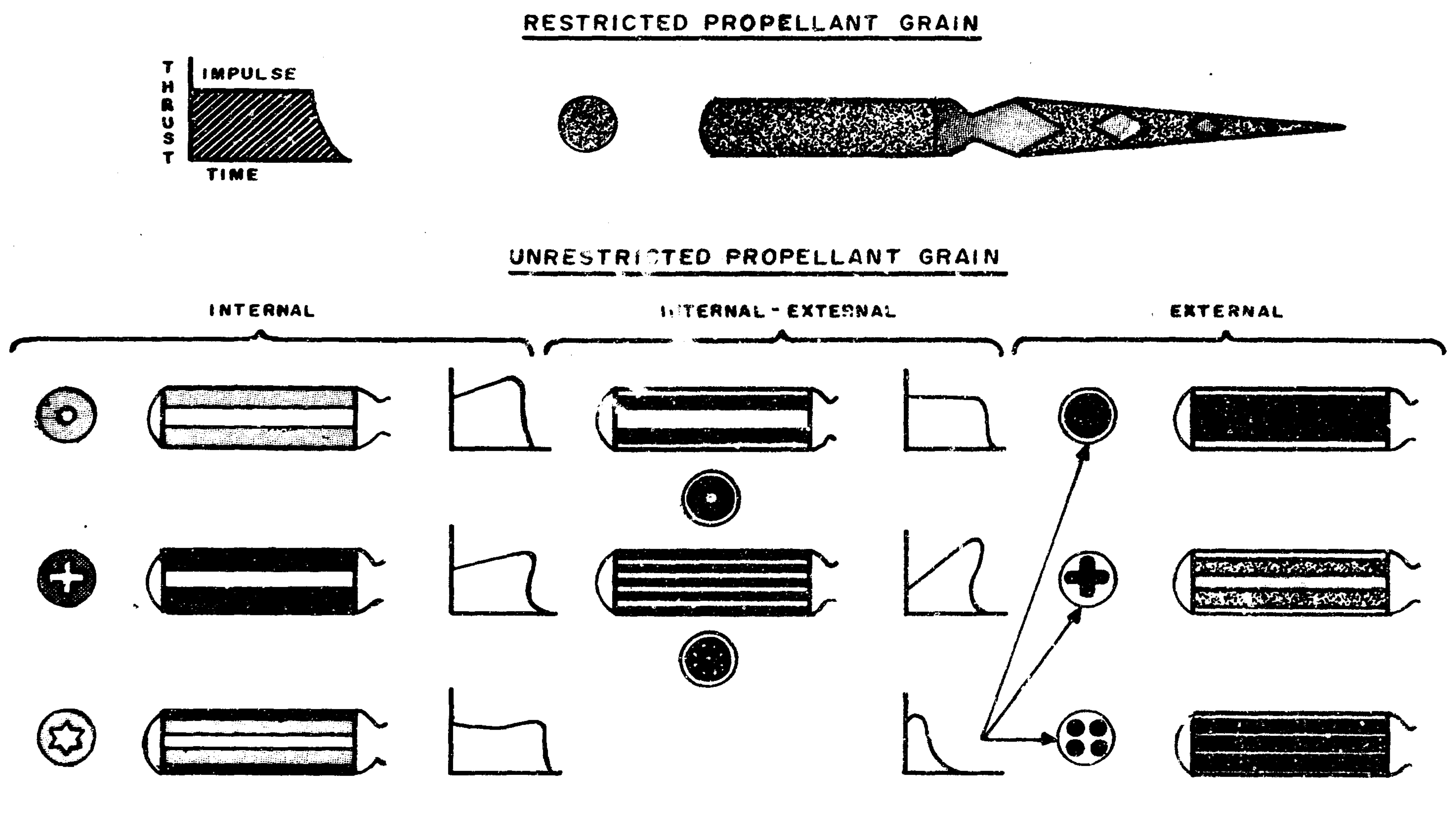



FIG. 2-4: SOLID PROPELLANT SYSTEMS

## V. PYROTECHNIC COMPOSITIONS

### A. General

Pyrotechnic compositions are classed as low explosives that exhibit very little explosive value. This is due to their low rates of combustion and the liberation of relatively little gas per unit weight of composition. Solid products of combustion represent more of their mass than the gases produced. They produce considerable light and are used extensively for signal and illumination purposes. Pyrotechnic compositions have been used for centuries for military purposes but in this century they have become important because of the increased technical requirements of modern warfare. Many pyrotechnic compositions have been developed for aerial observation, photography, bombing, heat, light, sound and smoke purposes. Also, compositions for tracers, smoke signalling, light signalling, spotting, tracking, delay fuze powders, igniters and incendiaries are considered pyrotechnics. All contain similar ingredients that undergo chemical exothermic reactions.

Physically, pyrotechnic compositions are mixtures of finely powdered elements and compounds that are generally compressed in candle form.

### B. Composition

The important ingredients of a pyrotechnic composition are the fuel and the oxidizing agent. Other materials may be added to produce the desired effects, such as intensified color and decreased burning rate. These materials may also be effective as binding agents or waterproofing agents. In the various compositions an added material may be effective in more than one of the foregoing capacities. The compositions generally are not chemically balanced. Atmospheric oxygen aids in the "cigarette burning" of the candle-form pyrotechnics and the need for a high percentage of oxidizer is not necessary. This results in the use of an excess of fuel and increased light intensity.

#### 1. Fuel

Powdered magnesium, aluminum and their alloys are generally used as fuels in pyrotechnic compositions, however, calcium silicide, charcoal, sulfur, silicon, zirconium, titanium and metallic hydrides may be used. Materials added as color intensifiers, binding agents and waterproofing agents also act as fuels if they are combustible.

#### 2. Oxidizers

The principal oxidizing agents used are determined

by the desired color of light, luminous intensity and burning rate. The nitrates of barium, strontium, sodium and potassium and the peroxides of barium, strontium and lead are among the most important oxidizing agents used. These compounds can supply the oxygen necessary for combustion of most of the fuel present in a composition. The remainder of the oxygen is supplied by the oxygen in the atmosphere.

3. Color Intensifiers

The most effective color intensifiers are compounds of chlorine. Organic chlorine compounds are preferable to inorganic compounds because of the hygroscopicity of many inorganic chlorine compounds and their incompatibility with the metals used as fuels. A few of the more important color intensifiers used are hexachlorobenzene, polyvinyl chloride and chlorinated waxes, rubbers and plastics. These agents decompose to form metallic chlorides during combustion and produce characteristic color bands found in the flame spectrum. These agents may also serve as fuels, combustion retardants and binding agents.

4. Retardants

Retardants added to pyrotechnic compositions are used to reduce the burning rate of the fuel-oxidizer mixture. These retardant materials must produce little or no effect on the color intensity of the composition. The retardants act as inert diluents or retard the burning rate of the metallic fuels by burning at a considerably slower rate than the fuels. Calcium carbonate, sodium oxalate, strontium resinate, titanium dioxide, polyvinyl chloride, ethyl cellulose, paraffin, linseed oil, castor oil, asphaltum and sulfur are the important retardants in use. Many of these compounds act as color intensifiers, fuels, binding agents and waterproofing agents.

5. Binding Agents

Binding agents are generally required to compress the pyrotechnic compositions into a dense coherent candle form. The metallic fuels and the inorganic oxidizing agents usually are non-adhesive. Polyester and sulfur plastics are the most widely used binding agents but polyvinyl chloride, ethyl cellulose, metallic resinates, oils, waxes and asphaltum are sometimes used. Many of these binding agents perform in a dual capacity.

6. Waterproofing Agents

Waterproofing agents are necessary in many pyrotechnic compositions because of the reactivity of metallic magnesium and aluminum with certain pyrotechnic compounds in the presence of moisture. Also, the nitrates and peroxides are usually hygroscopic. The waterproofing agents are dried linseed oil, acidified potassium dichromate, waxes, metal resinates and natural or synthetic resins. They are used to coat the metallic fuels or may be distributed throughout the composition.

C. Characteristics of Pyrotechnic Compositions

The important functioning characteristics of a pyrotechnic composition are its luminous intensity (candle power), burning rate, color, color value and efficiency in light production. The common characteristics for photoflash compositions are peak intensity, time required to reach peak intensity and the integral light in a required exposure time. Other important characteristics must be considered because pyrotechnic compositions are low explosives and must withstand loading, handling and storage operations. They are sensitive to static electricity and radio frequency, impact and friction, ignitability, stability and hygroscopicity. All pyrotechnic compositions must have explosive characteristics as well as pyrotechnic characteristics.

D. Uses of Pyrotechnic Compositions

Pyrotechnic compositions are used in a wide variety of ammunition products. The most important uses are in projectiles, flares, photoflash cartridges and bombs, signals, tracers, simulated ammunition, target identification bombs and in nose-cone or war-head recovery projects in the rocket and missile programs.

## VI. HIGH EXPLOSIVES

### A. General

A high or detonating explosive is a substance in which the transformation from its original composition and form, once initiated by suitable means, proceeds with virtually instantaneous, continuous speed throughout the total mass of the charge. The high rates of reaction and the high pressures are accompanied by the evolution of a large gas volume, heat, noise and a widespread shattering effect. The extreme rapidity of decomposition, termed "detonation," takes place in a manner similar to rapid combustion or with rupture and rearrangement of the molecules of the substance. The disruptive effect of the reaction causes many explosives to be valuable as bursting charges but precludes their use as a propellant. The gases formed develop excessive pressures that may burst the combustion chamber or the barrel of a weapon.

The compositions of high explosives usually contain nitrated products of organic substances or nitrogen containing inorganic substances. They may be mixtures of both. A high explosive may be a pure compound or an intimate mixture of several compounds. Ingredients that impart desired stability and performance characteristics are added.

High explosives are divided into primary and secondary explosives. The principal difference between primary and secondary explosives is the means of detonation. Primary high explosives are detonated by means of simple ignition, including spark, flame, impact and other primary heat sources. Secondary explosives require a detonator and frequently a booster for actuation.

The detonator used to detonate secondary explosives contains, as the essential element, a primary high explosive that is easily ignited. The detonator may be more complex if constructed with timing devices, safety mechanisms and other special features. The booster consists of a highly sensitive, secondary high explosive that reinforces the detonation wave to the main explosive charge. The main explosive charge is a secondary explosive.

### B. Primary or Initiating Explosives

Primary or initiating high explosives include primary compositions and initial detonating agents.

#### 1. Priming Compositions

Priming compositions are physical mixtures of materials that are extremely sensitive to impact

or percussion. The material mixtures may include the initial detonating agents; lead azide, mercury fulminate or lead styphnate. The application of impact or percussion to these mixtures causes very rapid auto-combustion but not detonation. The detonation is prevented by the dampening effect of added inert ingredients such as antimony sulfide, lead thiocyanate, ground glass or sulfur. The products of auto-combustion of priming compositions are hot gases and incandescent solid particles.

The priming compositions consist of physical mixtures of one or more initial detonating agents, fuels, desensitizers and binding agents.

The oxidizing agents used in priming compositions are potassium chlorate and barium nitrate. The fuels used are lead thiocyanate, carbon black, antimony sulfide and calcium silicide. Antimony sulfide and calcium silicide are also used to sensitize the compositions to friction or percussion. Carborundum and ground glass are used as sensitizers. The explosive ingredients generally are the sensitive-initiating compounds or the non-initiating compounds. Shellac, gum arabic and gum tragacanth are the major binding agents used and may also serve as fuels.

Priming compositions are used for the ignition of initial detonating agents, black powder igniter charges and propellants in small arms ammunition.

2. Initial Detonating Agents

Initial detonating agents are high explosives that are extremely sensitive to heat, impact and friction. They undergo detonation when subjected to a flame or percussion. They are used to initiate detonation of the lesser sensitive high explosives, comprised of bursting charges, demolition high explosives and dynamites. Most initial detonating agents have lower rates of detonation and brisance values than the explosives they initiate. Since they include azides, fulminates and diazo-, nitro- and nitroso-compounds, several of the initial detonating agents used are less stable than the non-initiating explosives. Many compounds that have satisfactory initiating characteristics are too unstable or sensitive for use in ammunition. Consequently, those in use as initial detonating agents are limited in number.

The initial detonating agents in use are:

Lead Azide

Mercury Fulminate

Diazodinitrophenol

Lead Styphnate

Tetracene

C. Secondary or Non-Initiating Explosives

1. General

Secondary or non-initiating high explosives include explosives that require initiation to detonation by another explosive. They are used as boosters, bursting charges, blasting charges and demolition materials. They mav be divided into the following types:

a. Single-Compound Explosives

b. Binary Explosives

c. Plastic Explosives

d. Dynamites

2. Single-Compound Non-Initiating High Explosives

Single-compound high explosives include inorganic and organic compounds. Ammonium nitrate is the most widely used inorganic explosive. The organic compounds include nitrates, nitro-compounds and nitroamines. These organic compounds are nitrocellulose, nitroglycerin, nitroguanidine, nitrostarches, trinitrotoluene (TNT), Explosive "D", cyclonite (RDX), pentaerythrite tetranitrate (PETN), haleite and tetryl.

3. Binary Non-Initiating Explosives

There are three (3) types of binary explosives manufactured. One is produced by mixing trinitrotoluene (TNT) with another explosive. A second type is made by mixing TNT with another explosive and a non-explosive material such as aluminum. The third explosive contains TNT and powdered aluminum. The aluminum increases the temperature of the explosive and decreases the brisance but gives the explosive a high blast potential. Binary explosives are superior

to TNT with respect to fragmentation and blast effect. Binary explosives are amatol, tetrytol, picratol, torpex, tritonal, ammonal, pentolite and ednatol.

4. Plastic Non-Initiating Explosives

The development of two (2) types of plastic non-initiating explosives was the result of limitations involved in the melt-loading of other explosives with TNT. Also, two (2) other requirements brought about this development, namely, the requirement for a highly brisant explosive that could be press-loaded without undue hazard and the need for a demolition explosive that could be hand-shaped.

RDX (cyclonite), a high brisant explosive, was selected and mixed with other explosive or non-explosive materials to produce the plastic explosives.

One of the two types consists of RDX and a desensitized wax in a mixture suitable for press-loading. The other type consists of RDX and a binding agent that forms a putty-like mass capable of being hand-shaped.

The plastic explosives now in use include the series of Compositions A, B, C and D.

a. Compositions A, A-2 and A-3 are composed of ninety-one (91) per cent RDX (cyclonite) and nine (9) per cent wax. The RDX will vary in granulation and the wax may be either beeswax or petroleum-derived wax.

b. Composition B consists of a 55:40:5 mixture of RDX to TNT and a desensitizing wax.

c. Compositions C, C-3 and C-4 are plastic demolition explosives that can be shaped by hand.

   Composition C contains an eighty-eight (88) per cent RDX and twelve (12) per cent of a non-explosive oily plasticizer.

   Composition C-3 contains seventy-seven (77) per cent RDX and an explosive plasticizer containing mononitrotoluene, a liquid mixture of dinitrotoluenes, TNT, tetryl and nitrocellulose.

   Composition C-4 contains ninety-one (91) per cent RDX and a desensitized mixture of poly-

isobutylene, motor oil and di-(2-ethylhexyl) sebacate.

d. Composition D-2 is a desensitized explosive mixture consisting of eighty-four (84) per cent paraffin and other waxes, fourteen (14) per cent nitrocellulose and two (2) per cent lecithin.

5. Dynamites

Operations requiring explosives, other than the standard military high explosives, for excavation, demolition and cratering must resort to the use of commercial blasting explosives. These blasting explosives, with the exception of black powder, are referred to as the dynamites. Most dynamites consist of high percentages of nitroglycerin and sodium nitrate, some carbonaceous materials, sulfur and an antacid. The dynamites may be exploded by flames, sparks, friction and sharp blows, including impact from bullets or shell fragments. They are subject to relatively rapid deterioration and require constant surveillance. Dynamites freeze at low temperatures and must be thawed before use. Dynamites may be exploded by a number-6 or larger commercial blasting cap or by the Corps of Engineers' special blasting cap. Dynamites are classified as straight, ammonia or gelatin dynamite.

a. Straight dynamite contains nitroglycerin as the explosive ingredient and a non-explosive filler. It has a high velocity of detonation that produces a shattering action. Straight dynamite is water resistant to a small degree and may be used underwater only if fired within twenty-four (24) hours after submersion.

b. Ammonia dynamite contains ammonium nitrate, in addition to nitroglycerin, as the explosive base. It has a medium velocity of detonation which produces a heaving action. It is not satisfactory for underwater use.

c. Gelatin dynamite is a jelly made by dissolving nitrocotton in nitroglycerin. It is highly water-resistant and suitable for use under wet conditions.

Specific data concerning the composition, type, strength and usage of these commercial dynamites may be obtained from the manufacturers.

## VII. IGNITERS AND IGNITION

### A. General

The effectiveness of a rocket depends upon the steady-state burning of the contained propellant system. The steady-state of propellant burning is always preceded by one or more transient processes designated collectively as the "ignition process." The ignition process is performed by a device known as an "igniter."

The igniter of a rocket motor must perform two (2) functions. One is to heat the propellant grain to ignition temperature and the other is to increase the combustion chamber pressure to a point where the reaction of the propellant responds satisfactorily. An igniter should accomplish these functions with only milliseconds of delay but without creating undue high pressures that will subject the propellant grain to excessive forces.

Primary initiation of an igniter is electrical in the majority of the present rocket motors because the location of the igniter in the rocket motor usually prohibits the use of a percussion type ignition system.

A type of igniter assembly (see Figure 2-5) consists of one or more electric squibs (electric match or initiators) and an igniting charge of black powder or pyrotechnic composition housed in a container. Leads (electrical wires) from the squibs are passed from the igniter housing to an external point where they can be attached to the electrical circuit. The squib contains a heat-sensitive composition that is initiated by the generated heat caused by the electrical impulse that passes through the electric lead wires. The ignition heat of the squib causes the ignition of the black powder and it then ignites the propellant. The black powder may contain a booster charge of other explosive materials. When more than one (1) squib is provided in an igniter the squibs are wired in parallel to provide assurance against misfires. For safety during handling, storage and shipment the igniter leads are shorted to prevent accidental ignition by stray or induced current or other sources of electrical energy.

### B. Ignition of Solid Propellants

Many solid propellants are ignited by a small quantity of black powder. The black powder is ignited by means of an electric match. The igniter consists of the electric match and the igniter material (black powder) encased in a container. An electric current applied to the lead wires of the squib produces sufficient heat to ignite the sensitive electric match or squib. The flame from the electric match spreads rapidly through the powder charge in the

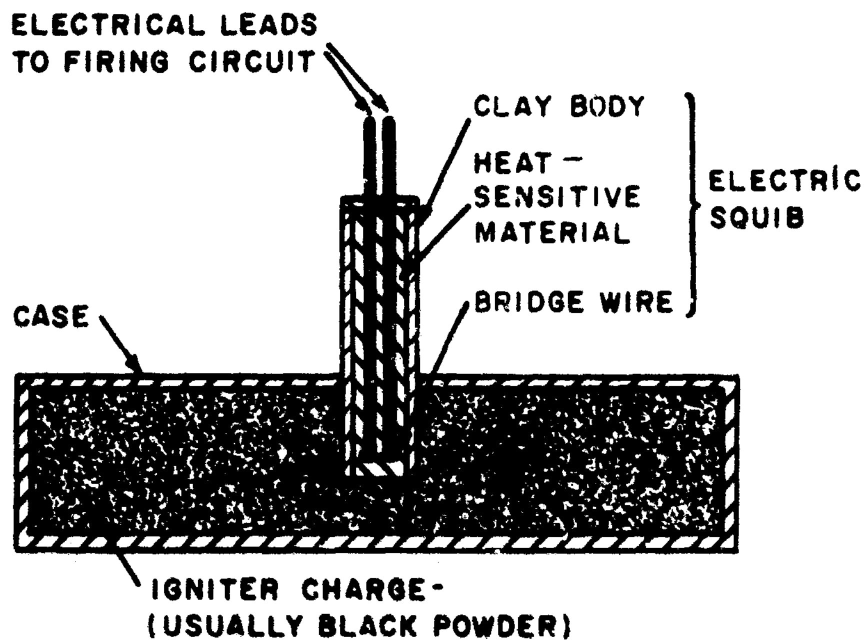



FIG. 2-5: A TYPE OF IGNITER ASSEMBLY

igniter, increasing the internal pressure until the igniter case is broken open. The products of decomposition of the igniter material transfer energy to the propellant by the three (3) mechanisms of energy transfer, including conduction, convection and radiation. The impingement of the hot, solid particles of the igniter material causes the propellant to ignite and burn in parallel layers. This burning produces hot gases and an increase in pressure that causes the propulsion of the rocket.

C. Igniter Design

Igniter design is influenced by the size and shape of the propellant grain and its composition, the location of the igniter in the rocket chamber and the free volume inside the rocket chamber. Therefore, design of an igniter for a rocket is usually the final step in rocket and missile design. The experience gained from trial and error results in frequent changes to igniter designs.

Generally, the design criteria for an igniter indicates a plastic or metal case containing an initiator and igniter material. The initiator is an off-the-shelf squib or a known electric match composition. However, the igniter materials vary according to the igniter performance required. Past and present igniter materials are black powder and double-base rolled powder or mixtures of both. Current and future missile programs indicate the use of borane pellets as igniter material.

Other principal design considerations for igniters are:

1. The type, grain size, formulation and moisture content of the igniter propellants

2. The size, direction, shape and temperature of the ignition flame

3. The location of the igniter with respect to the main charge

4. The surface condition of the main charge

5. The quantity of hot solid particles in the igniter gases

6. The quantity of debris ejected through the nozzle at the start

7. The nozzle closure rupture pressure

8. The time-pressure relationship between igniter pressure and the operating pressure of the rocket

9. The time delay between the electrical signal and the first pressure rise.

10. The construction, fabrication and fastening of the igniter case

11. The electrical energy.

D. Initiators

The electrical initiators or squibs consist of two (2) embedded electric leads and a bridge wire that short circuits the leads. The bridge wire is heated by the passage of an electric current. A heat-sensitive material is normally applied as a bead to the bridge wire. The old electric match or initiator contained a clay body and a primer mixture "buttered" around the bridge wire at the end. Later designs have enclosed the entire unit in a metal or plastic jacket, added a booster charge of black powder or other pyrotechnic mixtures and replaced the clay body with a rubber plug or a ceramic or glass insulator in a metal body.

Primer mixtures for the squibs may be mercury fulminate, lead styphnate or more complex mixtures of nitrostarch, lead azide, potassium chlorate and antimony sulfide. Gum arabic, red gum or a synthetic resin is used as a binder.

E. Igniter Materials

The original and most common igniter material is black powder, available in several mesh sizes ranging from a fine powder to very coarse granules.

Difficult ignition of igniters, used under adverse conditions, has brought about the addition of other materials to assure initiation, avoid misfires and produce higher temperatures and pressures. These materials, added to black powder, are chopped trench mortar sheet powder (double-base rolled powder), boranes and powdered metals.

Metal oxidizing agents have replaced the black powder in many of the newer ignition systems. The most common of these are magnesium or aluminum powder and potassium nitrate or perchlorate. Granular mixtures usually react too rapidly and the mixtures are usually pressed into a variety of different sizes and shaped pellets.

F. Igniter Containers

Originally the igniter containers for rockets were cotton cloth bags. These bags, which contained small quantities of black powder and an electric match composition, were closed and tied tightly with string. Containers of this type are used occasionally in experimental work. Due to the hygroscopicity of most igniter materials, a hermetically sealed container of a stronger, more endurable construction is required.

Many of the plastic containers, produced by an inexpensive rapid molding process, could be sealed against moisture. However, they were unsatisfactory because of their brittleness, reaction with the propellants and instability at elevated temperatures. New developments in plastics have again stimulated the use of hard, stable plastic containers.

The most widely used container for igniters at present is the common tin can that can be hermetically sealed. It has good handling properties and permits filling so that the contents can be tightly compacted. The tin-can container is not ejected when the rocket functions, instead, it ruptures or the cover is blown off.

Many igniters are now made with the container serving as a part of the rocket. These parts may be a head closure, part of the nozzle assembly or a part of the combustion chamber. In other cases the initiator and igniter container may be combined into a single unit, the body being machined from aluminum or steel. When more substantial containers are used, they should have a built-in rupture or blow-out mechanism that is reasonably precise to the condition under which it will rupture. These refinements are necessary when low variability in igniter performance is required.

## G. Igniter Types

The designs of various types of igniters for solid propellant rocket motors (see Figure 2-6) frequently are predicated by the shape of the grain configuration. However, their specific shapes are governed more by their location in the rocket chamber. The location of the igniter in the chamber is decided by the specific requirements imposed. Most rocket designs place the igniter in the front end of the rocket so the reaction products of the igniter will sweep over the entire length of the propellant grain. Some rockets use nozzle-end or internal igniters.

### 1. Head-end Igniters

Rockets utilizing fin-stabilizers have a relatively large length-to-diameter ratio. Consequently, space for an igniter is usually available at the head end of the rocket. Igniters for small caliber rockets will have a smaller outer diameter than the inner diameter of the rocket chamber. In larger rockets, the igniter may be a large can located in the center of the head closure or it may be in the form of a torus or a ring. The larger units have several squibs connected in parallel to insure functioning of the igniter and to increase the effectiveness of

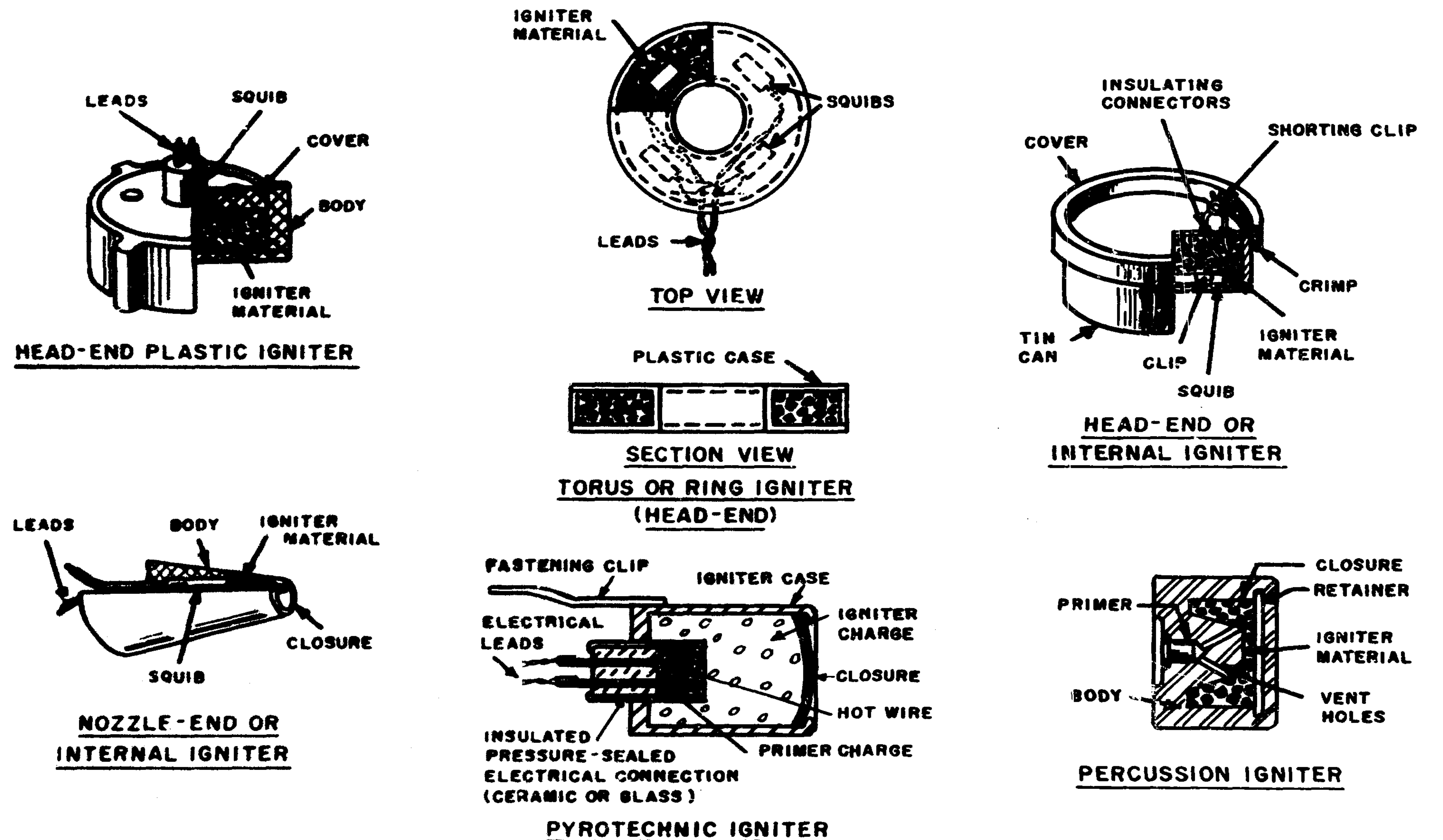



FIG. 2-6: VARIOUS TYPES OF IGNITER ASSEMBLIES FOR SOLID PROPELLANT ROCKET SYSTEMS

the burning of the large quantities of igniter materials.

2. Nozzle-end Igniters

Rockets of the spin-stabilizer type have severe limitations on over-all length and any increase in length to accommodate an igniter is prohibitive. Therefore, the igniter used in this type rocket is usually a nozzle-end igniter. A nozzle-end igniter is usually located in the center of the nozzle plate with the multi-nozzles located in a ring around it. By building the igniter into the nozzle plate the need for a container, as well as the possibility of container fragments plugging the nozzles, is eliminated.

Nozzle-end igniters may be used in single or multi-nozzled rockets.

3. Internal Igniters

Particular configurations of the rocket charges oftentimes indicate the desirability of having the igniter located in the interior of the charge. This type igniter is designated as an internal igniter.

Internal igniters may be nozzle-end or "bayonet" shaped igniters with outer diameters small enough to allow placement within the cored center of the grain. The "bayonet" shaped igniter may consist of a long plastic or metal perforated, plastic coated tube, filled with igniter material (black powder or borane pellets) and containing the initiators.

## VIII. EXPLOSIVE DEVICES AND ORDNANCE ITEMS

### A. General

Explosive devices and ordnance items are utilized in all types of missile weapons systems. In military ordnance terms an "explosive device" usually denotes an item that is designed and made specifically for a particular weapon. An "ordnance item" is referred to as one that is a standard, off-the-shelf item. However, in missile terms the two categories are used interchangeably. In this MANUAL the two terms will be used interchangeably.

The contrivances that are considered as explosive devices and ordnance items are used in rockets and missiles to perform certain functions before and during launch; during flight; and before, during and after impact. They are used to initiate various timed or sequenced system operations necessary for ignition; additional rocket thrust at separation; to facilitate sound fixing and ranging and to destroy the missile in the event of an emergency or an erratic flight.

Explosive devices and ordnance items are usually electrically initiated. Those used in rockets and missiles include igniters and igniter assemblies, initiators, detonators, destructors, primers, squibs and squib assemblies, gas generators, explosive bolts, cartridges and valves, safe and arming mechanisms, pyrotechnic and photoflash items and sound fixing and ranging bombs.

A general description of these items is presented, however, many of the devices are designed specifically for a particular missile and exhibit minor variations in shape, size and installation hook-up.

Igniters and ignition systems are discussed in Part VII of this Section.

### B. Explosive-Ordnance Devices

#### 1. Primers and Time Delay Devices

A relatively small and sensitive initial explosive, on being activated, initiates the functioning of the explosive train. This initial explosive is termed as an electrical, chemical or mechanical primer and is used to initiate the next element in the explosive train which is usually a time delay device or detonator. Primers are either brisant flame producers or act as impact starters to detonators that have sensitive explosives at one end.

There are two (2) types of primers; instantaneous primers and those with special time delay elements (see Figures 2-7 and 2-8). Both types react quickly and are moderately powerful.

The most commonly used primer in the missile industry is the instantaneous electric primer. This primer consists of an ignition element and a base charge, assembled to form a single unit. The igniter element consists of the lead wires or contacts molded into a plug and a bridge wire fastened to the contacts. The bridge wire is surrounded with a suitable primary explosive. The base charge in the primer contains a quantity of sensitive explosives pressed into a cup and is capable of initiating the next element in the train.

Primers are classified in accordance with the method of initiation, namely electrical, chemical or mechanical. The mechanical category includes percussion, stab, friction or shock.

In size, primers range in outside diameter from 0.190 to 0.281 inches and from 0.375 to 4.5 inches in length. The time delay element added to primers increases the length approximately 0.17 inches for each second of time delay.

2. Squibs and Squib Assemblies

A squib is a flame-producing device with little or no brisance. They are used primarily to ignite deflagrating materials such as black powder, metal-oxidizing agents and fuzes.

Some of the factors considered in the design criteria of squibs are ignition temperaturo, ignition time delays, speed of reaction, burning efficiency, fracturing effects, fragmentation and environmental conditions.

In size, squibs range from matchhead size to one-half inch in outside diameter and in length from one-half to two inches. Larger size flame devices are categorized as igniters. Also, some igniters may consist of a small unit squib or several of them placed inside the igniter case that contains the main charge of black powder, pyrotechnic or metal-oxidizing agent.

A squib may be an open or closed type (see Figure 2-9). The open type is a matchhead or a plug containing an open cavity. These are not protected from moisture and as a consequence are

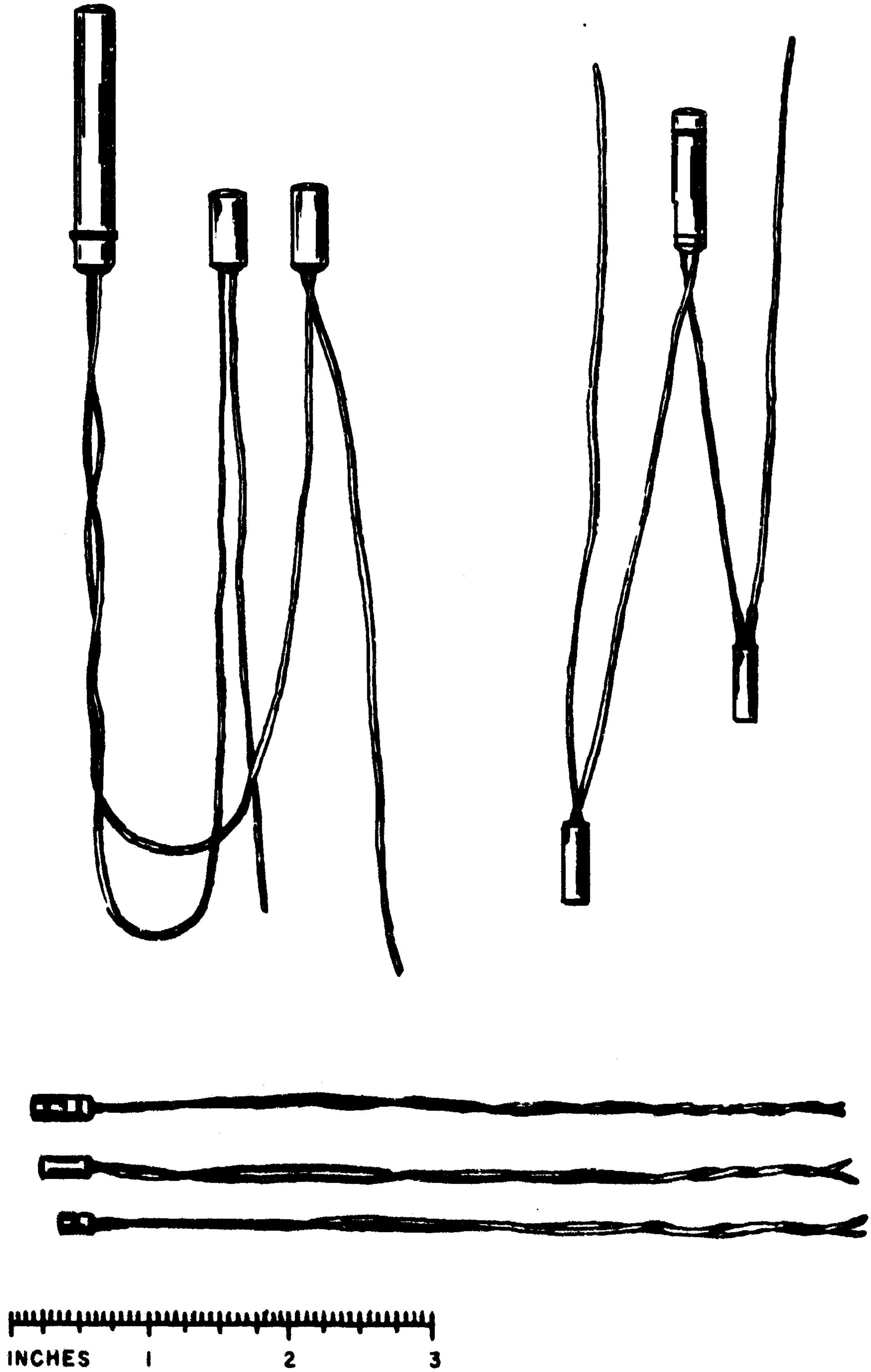



FIG. 2-7: PRIMERS

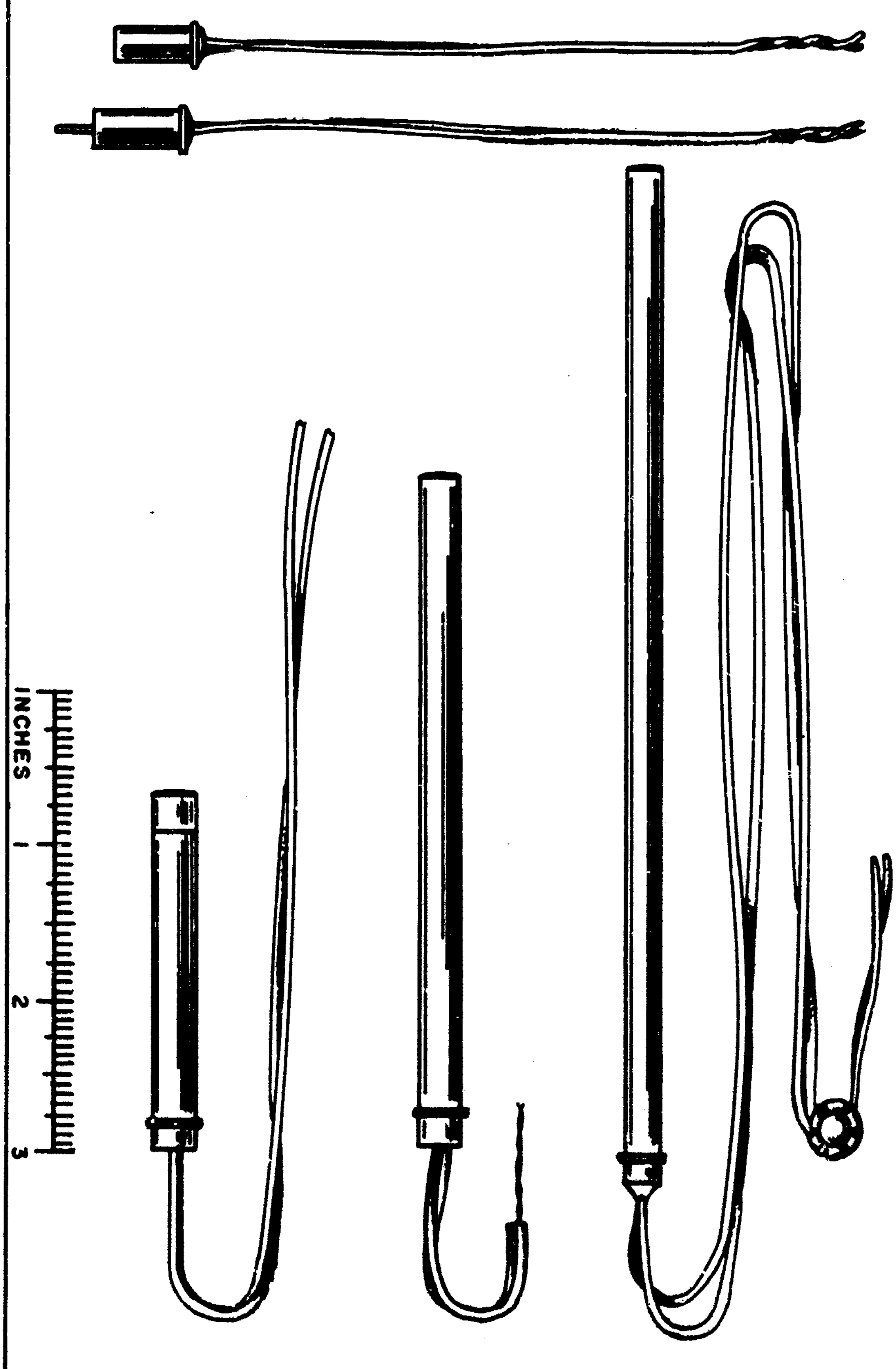



FIG. 2-8: TIME DELAY DEVICES

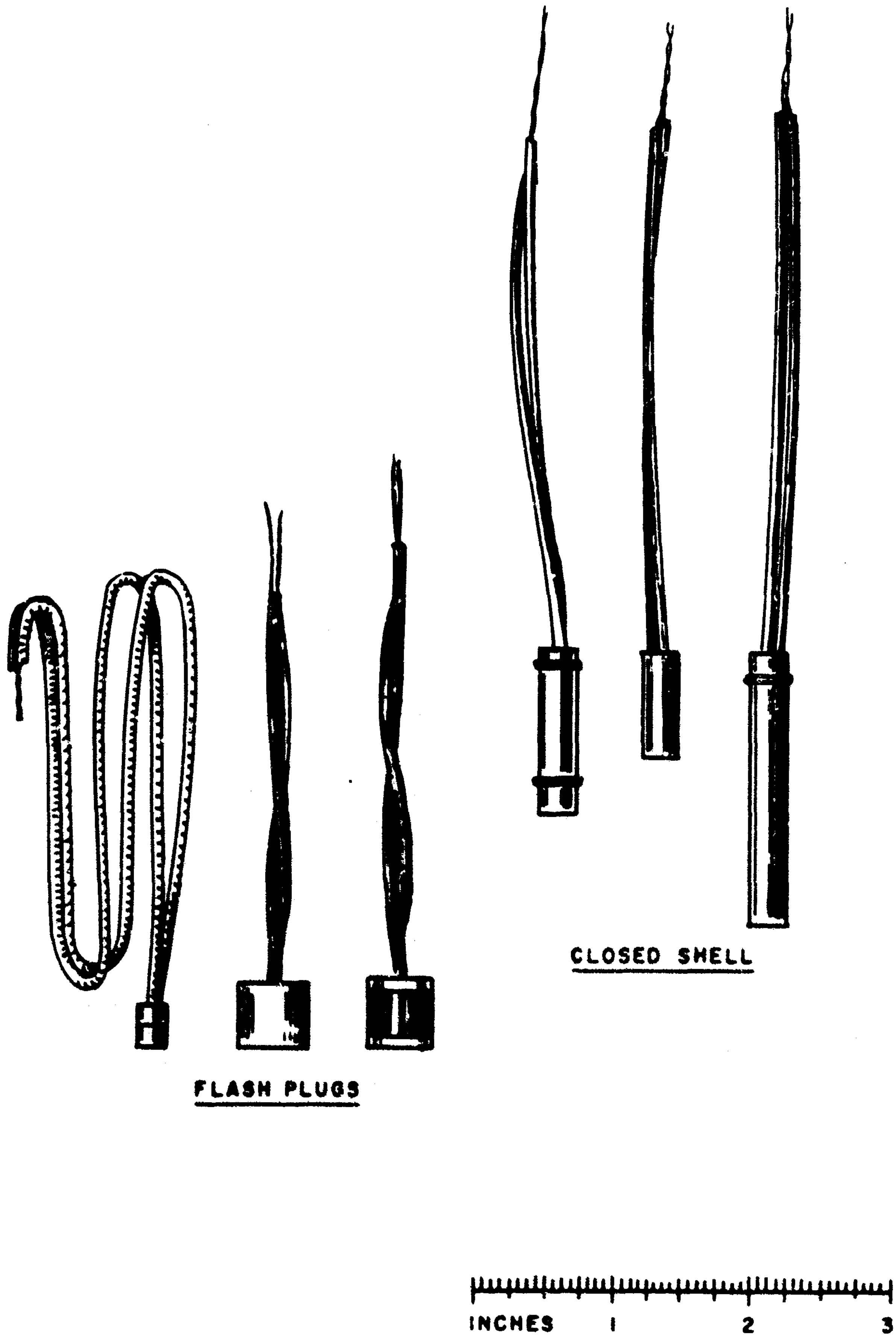



FIG. 2-9: SQUIBS

seldom used. However, if there is no external-sealing barrier, such as an igniter case or if moisture protection is required, they should be enclosed in a more protective assembly (see Figure 2-9). Also, since the gases produced by ignition of the open squibs are not confined, the brisance and action is considerably less.

A more protected or closed squib consists of a metal or plastic case with a port in the case, covered with a thin diaphragm cemented in place. The seal is dependent on a lacquer film and the proper joining of parts. It is not reliable unless these conditions exist.

A fully enclosed squib is made with a number of variations: metal shell-plastic plug, plastic shell-plastic plug, metal shell-hermetic seal typo plug, metal shell-rubber plug, etcetera. The detailed design possibilities are unlimited.

A metal shell tends to confine the gases until the high pressure causes a sharp eruption of the shell. Aluminum is better than copper in respect to eruption but copper is better for electrical conductance. Either is suitable if added features are used, such as thin or scored bottoms. Special design is required if shell fragments are undesirable. Plastic shells are used frequently but are susceptible to heat damage, chemical or vapor reaction.

By using combustible materials that burn rather than explode it is possible to reduce brisance. Therefore, the shell wall will melt rather than shatter.

The majority of squibs are designed to be included or sealed in the next element in an explosive train.

3. Detonators

A combination of a primer and another less sensitive explosive charge comprises a detonator. The detonator is normally the element in the explosive train which effects the transition from deflagration to detonation. A detonator will initiate a high order of detonation in high explosives. The detonator performs three (3) distinct functions which are initiation to deflagration, transformation of deflagration to detonation and the transfer of the detonation impulse to the next item in an explosive train. The primary difference between a primer and a detonator

is the quantity of the charge. Uses for detonators are the same as primers except for the additional uses of initiating boosters or high explosive charges.

Detonators range in size from 0.190 inches to 0.300 inches outside diameter (see Figure 2-10). The length ranges from 0.300 inches to 4.5 inches. They may contain time delay elements similar to the primers and squibs. The time delay elements increase the length approximately 0.2 inches for each second of time delay.

The explosive in detonators may be PETN, "reconsolidated-pelleted" tetryl, lead azide, lead styphnate and mercury fulminate.

Detonators are classified according to the method of initiation, as flash, stab or electric detonators. They are described below:

a. Flash Detonators

The flash detonator is designed to deliver a detonating impulse when acted upon by a heat impulse or a detonating impulse generated by a previous element.

The flash detonator may also be used as a relay where the gap over which the detonation must be transmitted is too great for the primary detonation to be effective.

b. Stab Detonators

The stab detonators usually function as the initiating element of a fuze. The element is highly sensitive to the action of a stab-firing pin. The stab detonator produces a detonation which can start the action of an explosive train by the initiation of a tetryl lead-relay detonator or a booster charge. The stab detonator is initiated by a firing pin which is generally driven by one of three different means; impact with a target, spring action or gas pressure.

c. Electric Detonators

The electric detonator is ordinarily used to actuate a booster lead (normally tetryl). The electric detonator does not require the use of a flash detonator, therefore, the explosive train from electrical initiation to lead-in is included in a single unit.

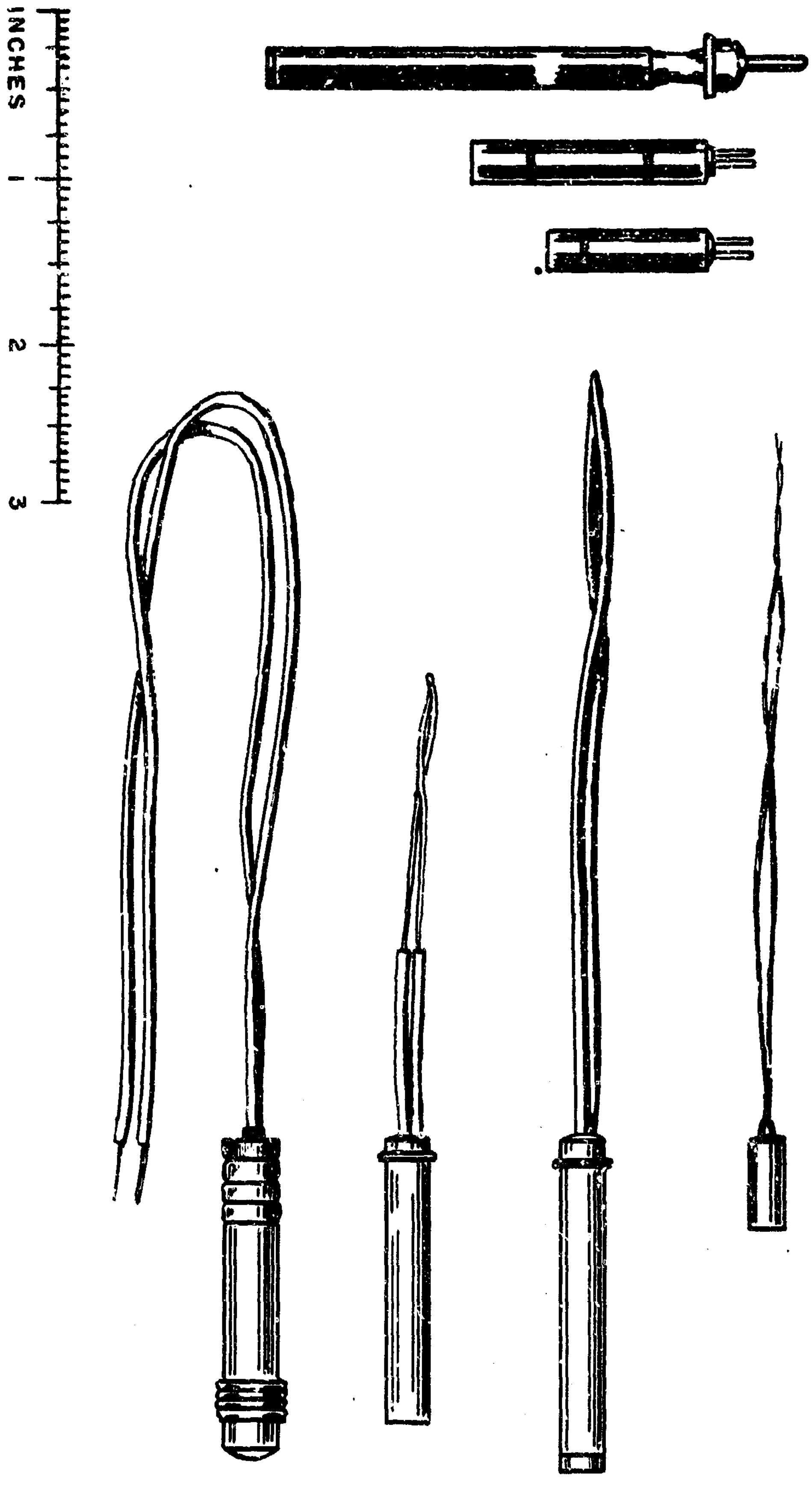



FIG. 2-10: DETONATORS

The electric detonator, from the standpoint of safety and space utilization, does not provide the high degree of design contained in a primer-flash detonator combination.

The detonator-primer combination is ordinarily composed of an ignition element, intermediate charge of a primary explosive and a base charge assembled in a single cup. The combination is not rigid and in some cases there are more than three (3) charges. In others no intermediate charge of a primary explosive is necessary. The combination may contain delay elements.

4. Detonating Primers

A device that is equivalent to a very large and powerful electric-blasting cap is termed a "detonating primer." The power exhibited by this device categorizes it as a detonator primer instead of a blasting cap.

Some of these detonating primers contain 20-30 grams of PETN and the overall dimensions range from five-eighths to three-quarters of an inch in diameter and a length of 2.5 to 3 inches.

A detonating primer is sufficiently powerful to detonate large high explosive charges directly or cause powerful fracturing effects in the immediate vicinity.

5. Boosters

A booster is defined as an extra charge of high explosive without the initiating explosive device. A "warhead booster" is a high explosive substance sufficiently sensitive to be actuated by small explosive items and powerful enough to cause detonation of the main explosive charge. Also, in a launching system, a booster is defined as an auxiliary propulsion system which travels with the missile and may or may not separate from the missile when its impulse has been delivered.

In explosive devices the booster charge is the extra charge of high explosive used in initiators, primers and destruct units (see Figure 2-11).

The explosive-device boosters are made with metal shells loaded with high explosives and sealed against moisture penetration. Some boosters are made of plastic-high explosive mixtures that are inherently water resistant and can be easily cast into a variety of shapes and sizes (see Figure

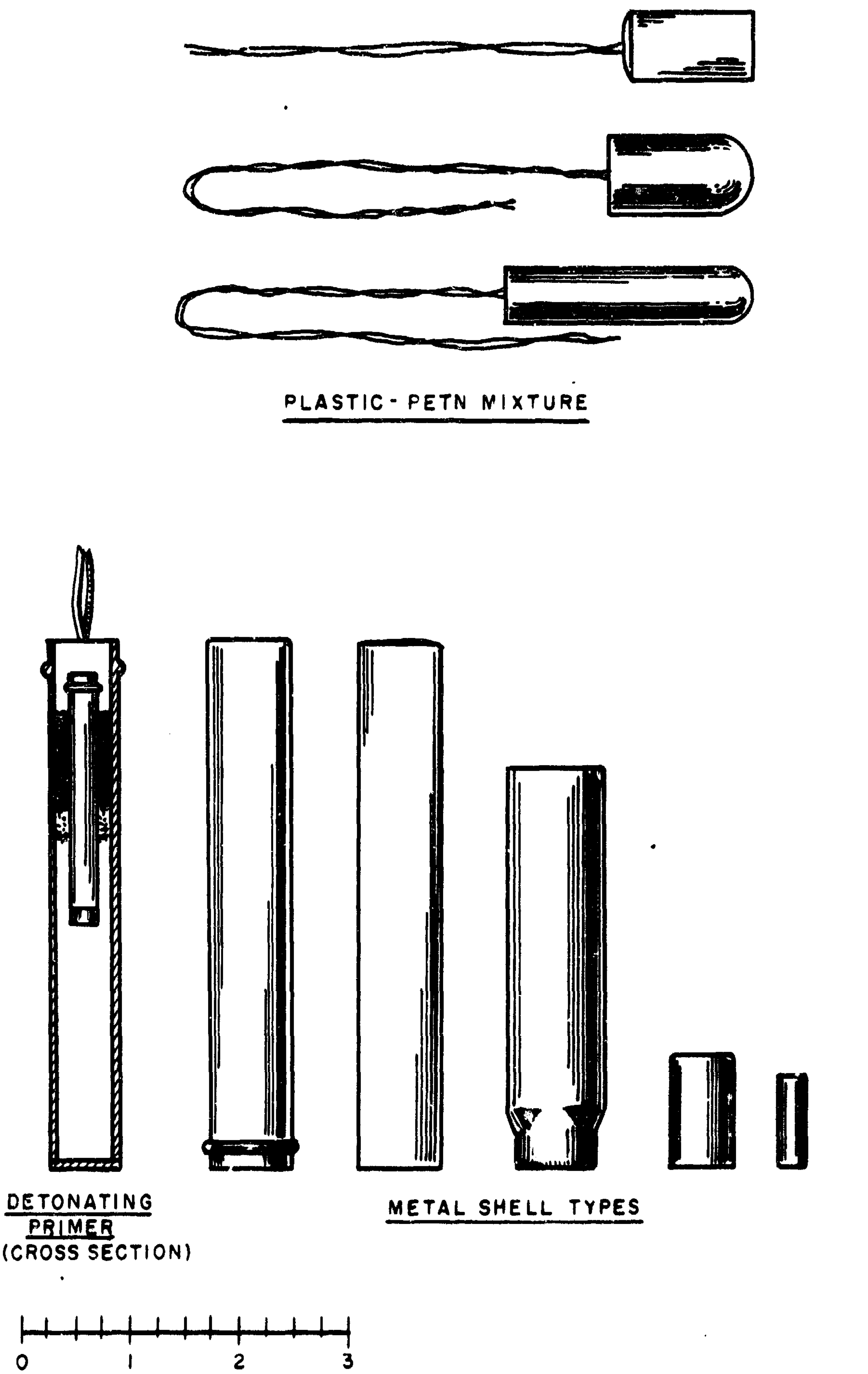



FIG. 2-11: BOOSTERS (EXPLOSIVE DEVICE)

2-11). Wells or through-holes are formed in these propellants for attachment of detonators or detonating primacord.

6. Explosive Bolts

Explosive bolts (see Figure 2-12) consist of a special or standard sized bolt with the explosive either separate from or an integral part of the bolt. These fracturable fastenings are constantly being developed for specific performances. The explosive components of the bolt are an initiator and a high explosive for shock wave production. The shock waves cause tensile failure of the bolt. Other types of explosive bolts are cut into by means of a hot jet or are blown apart by pressure. The explosive bolt is used in the final assembly and torqued to the desired load. Then the explosive unit is screwed into the head of the bolt and wired into the circuit by means of two (2) lead wires. The circuit is insulated from the ground.

These bolts may be designed to prevent mushrooming or fragmentation at the fracture line. However, if greater bolt strength or faster action is required, suitable shields can be installed to prevent missile damage or personnel injury.

Explosive bolts are used in applications involving the separation of nose cones, jettisoning of fuel tanks and emergency release systems.

7. Explosive Cartridges

The explosive cartridges used in the missile industry produce pressure sufficient for separation of umbilical cords between missile stages, separation of missile stages during flight, etcetera. These cartridges may be termed as pressure cartridges, pressure squibs, separation cartridges or explosive cartridges.

These cartridges consist of an initiator and additional pressure-producing explosives. The device produces high pressure over a period of milliseconds.

The cartridges are used in jettison, ejection, separation and launch of missiles, rockets, bombs, seats and canopies.

8. Explosive Valves

Explosive valves are devices used to produce pres-

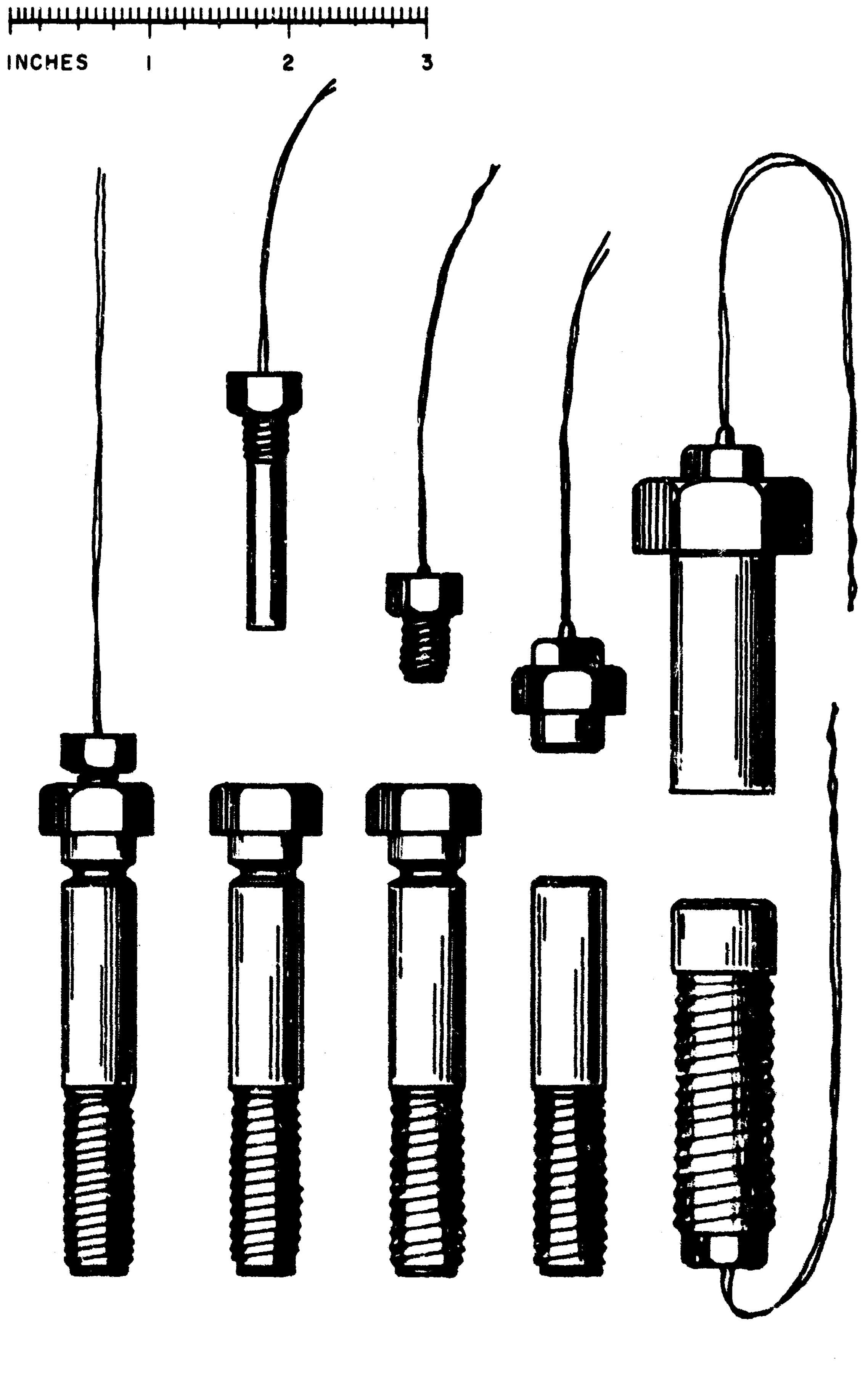



FIG. 2-12: EXPLOSIVE BOLTS

sure for auxiliary power supplies, stage-separation functions, fuel and oxidizer starts and stoppages and to develop hydraulic pressures for explosive motors and hydraulic pumps.

The valves consist of a primer, initiator and a diaphragm. The diaphragm is ruptured by a ram or piston driven by the gas produced from the ignited primer and initiator.

9. Initiators

The primers, squibs, detonators, explosive bolts, cartridges and valves, gas generators, igniter and explosive motors use an initiator. Also, these items may be the initiators used as the initial actuating mechanism to begin an explosive train. Most electrically-actuated explosive devices consist essentially of an initiator with additional components added to perform a specific purpose or function. The initiator is the most sensitive part of the explosive device and its design reflects the safety, reliability and operational characteristics of the unit.

There are three (3) types of initiators:

a. The primer, designed to emit a shattering hot flash or flame

b. The squib, designed to emit a hot flash but not a blast effect

c. The detonator, designed to produce a high-velocity shock wave to trigger other explosives.

Primer and squib initiators are used to actuate igniters in guns, rockets, pressure cartridges, gas generators, etcetera. The detonator initiator is used to set off primer cord, destructors and other high-explosive devices.

A typical initiator is shown in Figure 2-13. The first part of the initiator is the AN-type electrical connector with two (2) terminal pins. Next is the insulating-pressure seal through which the electrical leads enter the primer-explosive container. The bridgewire, at the ends of the leads, is heated by the application of electrical current to initiate the explosive primer or bead that surrounds it. The ignition of the primer results in the ignition of the booster, which in turn ignites the main charge. The main charge provides the working power or desired effect. A closure disc

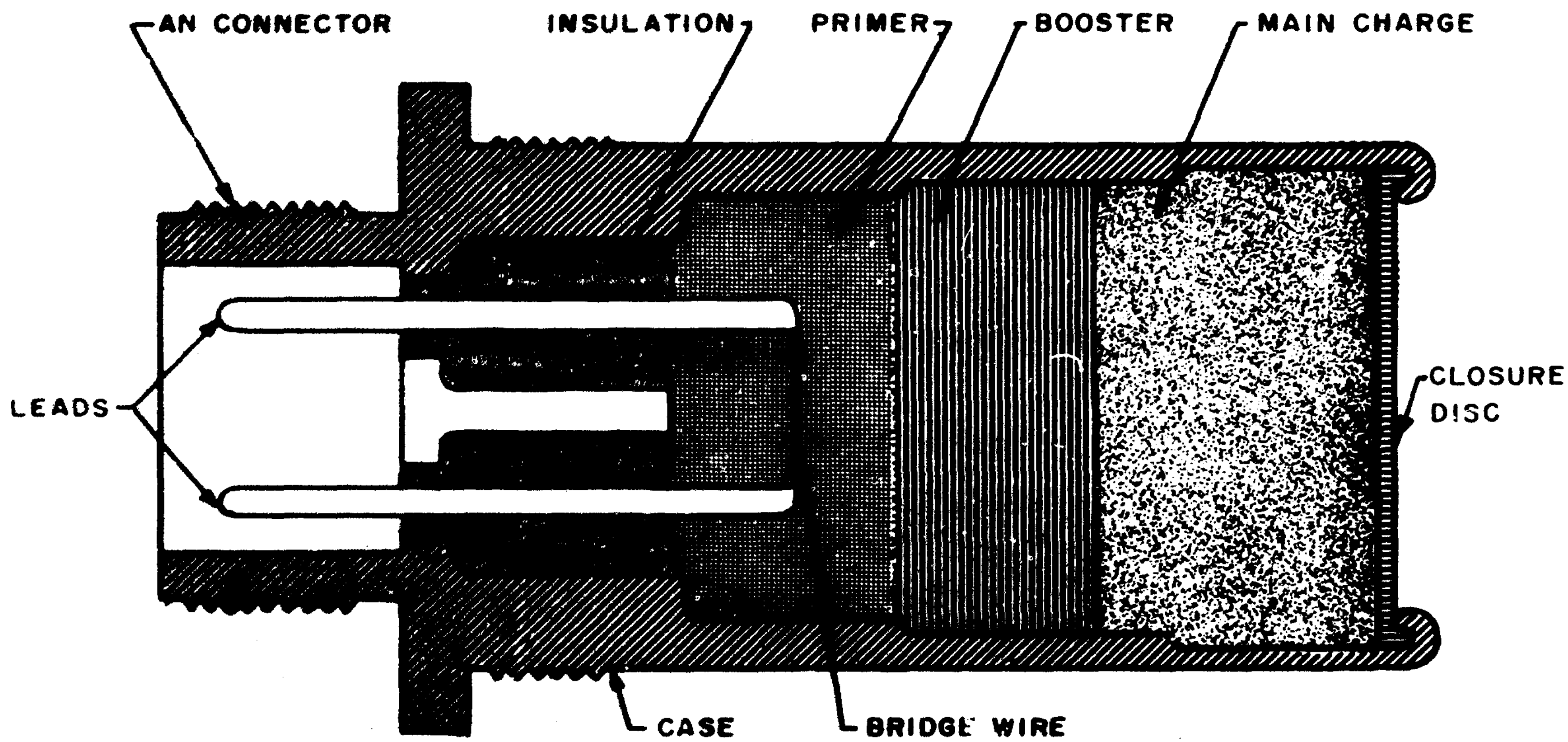



FIG. 2-13: INSIDE THE INITIATOR

is crimped into place for environmental protection.

Initiators may consist of a primer charge, a primer or a booster. Many initiators contain all three, a primer, a booster and a main charge. The combination of charges is determined by the required effect. The initiator is not always a separable component of an explosive device but is often an integral part of the pressure cartridge, explosive bolt or igniter.

Initiators are also divided into two (2) groups according to sensitivity; those which are sensitive and those which are insensitive. The bridgewire and bead are matched accordingly. The sensitive initiator may have a 25- to 1,000-milliampere fire-current characteristic. The insensitive initiator may have a one (1) ampere or more no-fire current characteristic. The fire or ignition characteristics of an initiator is not easily defined by its current or voltage rating. This is determined by an energy level which involves resistance, current and time.

The common initiator components are connectors, insulation, lead wires, bridgewires, primers or ignition beads, closures and sealants and case materials.

Three (3) common methods of electrical connections are used in the initiators. They are as follows:

a. Plug and socket, AN and MS connectors

b. A spring-contact pin to a center part of the initiator

c. Lead wires protruding from the explosive case and attaching to a terminal trip.

The common types of dielectric insulation used between the leads and the case of the unit are plastics, synthetic rubbers, phenol, glass and ceramics.

The common types of lead wires are stainless-steel wire, steel wire with an electro-tin plating, tinned copper wire and stranded-tinned copper wire. These wires usually terminate as pins in a connector or are commonly insulated by a vinyl cover, glass cloth cover or nylon or cotton jacket over celanese wrap. Frequently the wires are left bare.

The common types of bridgewires are the carbon

and wire bridge. Common bridgewire materials are nichrome wire and platinum-irridium wire. Bridgewire diameters run in thousandths and ten thousandths of an inch.

Common types of primer and ignition explosives are nitrocellulose, tetryl, lead styphnate, lead azide, mercury fulminate, black powder and DDNP (diazodinitrophenol).

Common closures are nitrocellulose or aluminum foil. The nitrocellulose is an explosive that is consumed in the explosion. The aluminum foil is reduced to aluminum oxide in the explosion. A common sealant is an epoxy resin.

Common case materials are stainless steel, steel, aluminum and gilding metals.

10. Gas Generators

A gas generator is an electrically initiated, solid propellant rocket motor designed to produce a constant gas pressure with controlled mass flow and temperature. The gas generator differs from the explosive cartridge in that the gas generator pressure is usually lower and lasts for a period of minutes. A gas generator consists of an ignition element and a solid propellant in a metal case. The case contains an orifice to vent the gas produced (see Figure 2-14). The gas output can be established and maintained uniformly within plus or minus five (5) per cent. Gas-outputs range from 100 to 10,000 cubic centimeters.

Gas generators are used for inflation of bags, power for electrical generators, power for missile control surfaces, to expel liquids, pressurize containers and move pistons in actuators.

11. Explosive Motors

The explosive motor consists of an initiator and some type of piston or bellows. The power or pressure generated is converted into mechanical motion by the pistons or bellows. The explosion and resulting pressure are contained in the motor. The movement provided by the motor is not reversible but remains positive until such time as the gas pressure leaks off or is released. Explosive motors are used for the actuation of explosive switches and mechanical detents (a pawl).

12. Destructors, Destruct Units and Primacord

High-explosive destructors or destruct assemblies

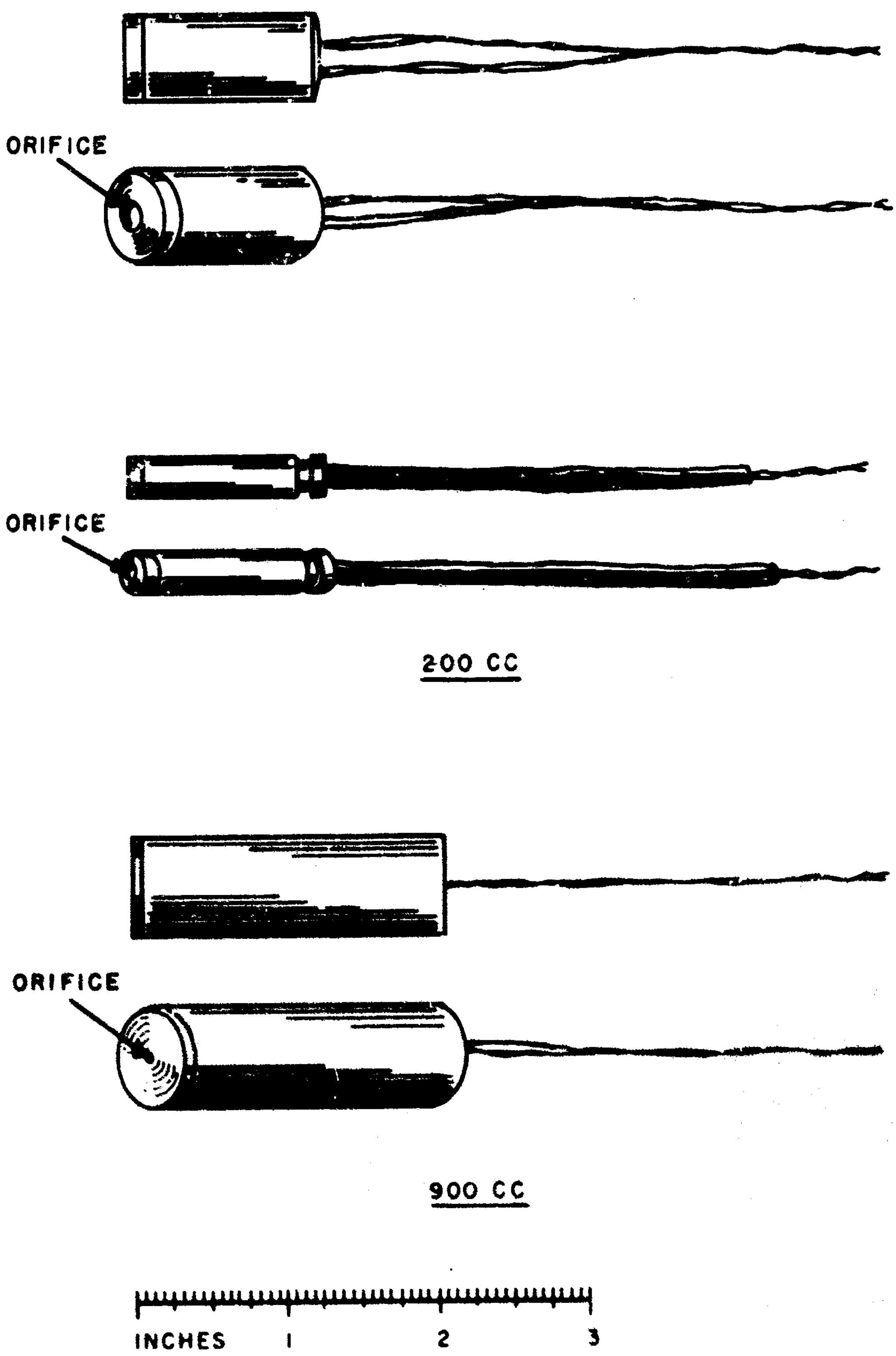



FIG. 2-14: GAS GENERATORS

are used to rupture the propellant and fuel tanks, destroy an errant missile or destroy a specific missile stage or component part.

Each destruct unit (see Figure 2-15) consists of a rotor and solenoid, primers, a safe and arming mechanism, a detonator, a safety firing pin and an initiator containing booster pellets. Strands of primacord lead from the booster pellets inside the initiator case, through booster retaining straps containing high-explosive booster material. The strands of primacord vary in number from one to ten and may be individual or clustered. The strands are attached lengthwise to the missile part to be destroyed.

Other types of destruct units include all of the component parts and the booster material in a single unit.

a. Primacord

Primacord used in destructors may be exposed to extreme heat or cold. When fuel tanks are to be ruptured, the primacord will be exposed to extreme heat. Therefore, an explosive core of RDX (cyclotrimethylenetrinitramine) is used because of its stability under high temperature conditions. The explosive core for extreme cold exposure is PETN (pentaerythrite tetranitrate) which is more reliable under low temperature conditions.

The two (2) explosives are approximately equal in power and brisance. RDX is less sensitive to initiation and will withstand higher temperatures than PETN. The melting point of PETN is approximately 285°F while RDX melts at approximately 385°F.

For purposes of identification the explosive core of RDX primacord is tinted pink.

The explosive wave of primacord travels approximately 21,000 feet per second.

RDX and PETN primacord is relatively safe to handle and store. It cannot be set off by normal vibration or friction, ordinary impact or sparks. It must be detonated. Due to its explosive core it is recommended that all primacord be handled and stored in the same manner as other explosives of the same hazard classification.

Primacord used in the missile industry may contain 30 to 1,500 grains of RDX or PETN per foot.

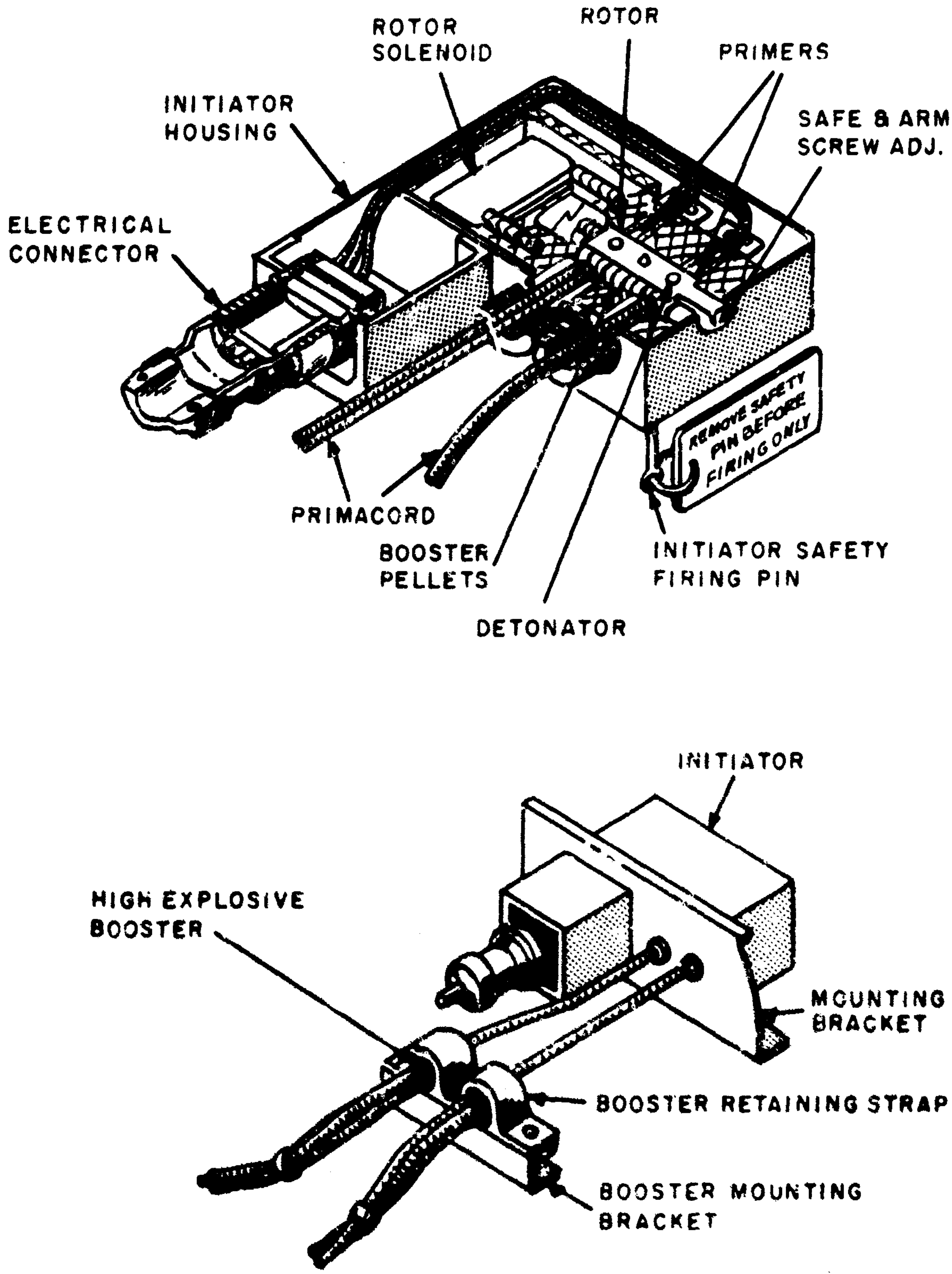



FIG. 2-15: MISSILE DESTRUCT ASSEMBLY

13. Safe and Arming Mechanism

A device used to interrupt the functional path between various explosive elements within an explosive train is termed a safe and arming mechanism. The arming consists of completing the functional path at the proper time. This is performed by a rotor turning the safety barrier or by removal of the barrier. The barrier may be a metal or plastic plate. Figure 2-16 illustrates the explosive chain in a safe and arming mechanism.

14. Explosive Actuators

Explosive actuators are designed to perform mechanical work with disruptive effect on the actuator case. The items included as explosive actuators may be squibs, primers or detonators or may be a term to connote a complete explosive unit. Examples of these complete units are explosive releases, explosive-cable (umbilical) cutters or explosive valves.

The squibs that are used as explosive actuators are the slower-acting pusher type. They contain slow burning metal-oxidizer mixtures, smokeless powder and black powder.

Primers include the faster-acting actuators which have little or no detonating action. Pressure rises are faster and the action is sharper.

Detonators used include the fastest actuators and contain high explosives that generate extreme pressure.

15. Non-Explosive Actuators

Non-explosive actuators (see Figure 2-17) may be defined as devices for converting the energy in an explosive to mechanical work, while, at the same time, confining the products of explosion so that no bothersome external flame or flying fragments are produced.

Operating times of these devices vary from a few milliseconds up to 50 seconds or more. Examples of non-explosive actuators are:

> Dimple motors, bellows motors, piston actuators, non-explosive switches, valves, specially constructed explosive bolts and gas generators and other self-contained operating devices fabricated or sealed

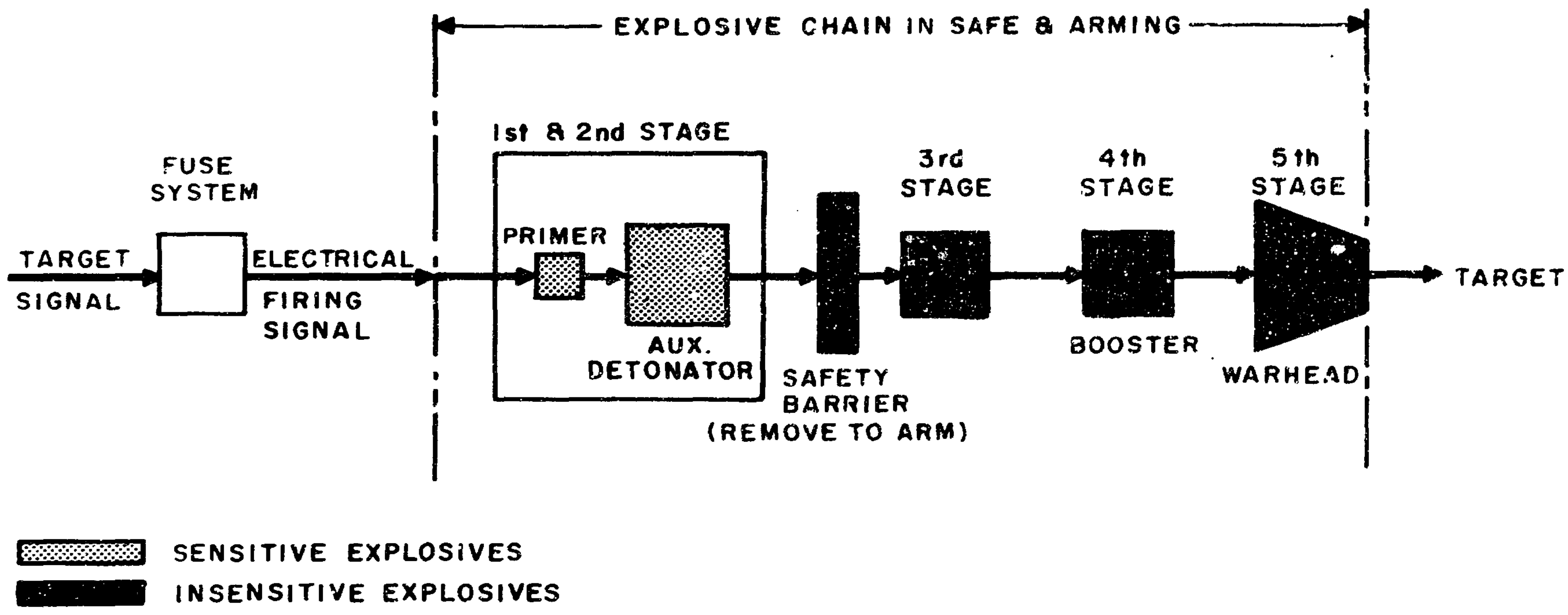



FIG. 2-16: EXPLOSIVE CHAIN OF A SAFE & ARMING MECHANISM

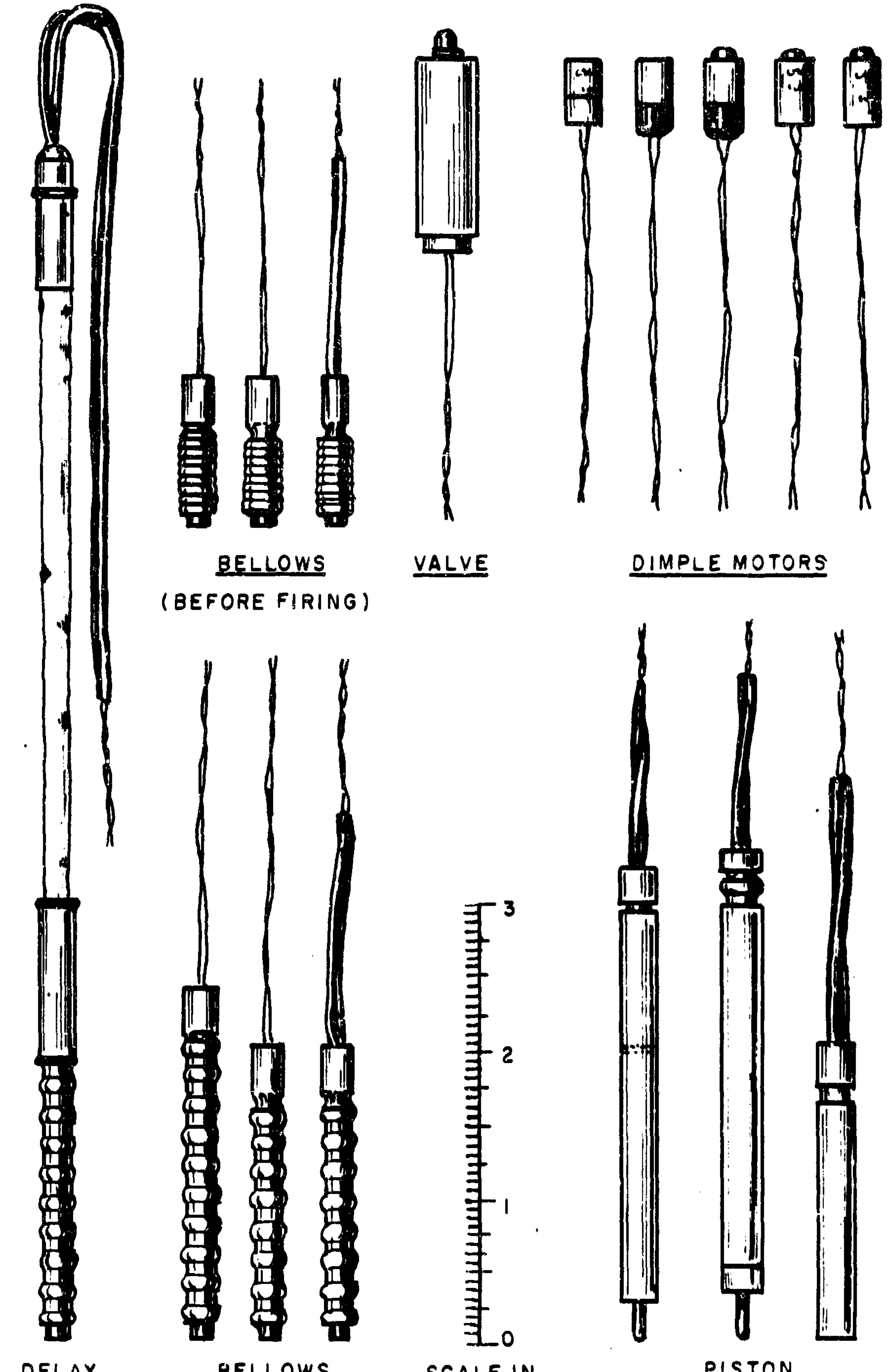



FIG. 2-17: NON-EXPLOSIVE ACTUATORS

against release of fragments.

a. Bellows Actuator

A bellows actuator is made by forming a thin cylindrical shell into a sealed bellows. When the internal mixture is ignited, producing a gas, the contracted bellows expands longitudinally with considerable force.

b. Switches (Non-explosive)

These devices contain small charges of propellant or gas-producing ignition compositions whose sealed-in gas pressure usually causes a mechanical piston motion of an internal moving part to close or open internal switch contacts (see Figure 2-18). Several varieties of switches have been developed for specific military applications. The switches are designed to function within several milliseconds or for ten (10) seconds or more. Some switches are designed with delay mechanisms.

These switches are frequently referred to as "explosive switches." However, this is a misnomer since an explosive rupture of a case is practically impossible.

Switch action may be single pole-single throw, normally open or closed, single pole-double throw, or multiple pole-double throw. The latter types are usually referred to as transfer switches.

16. Indicators

Indicators are non-explosive devices used to indicate simulated firing conditions. These indicators simulate the explosive devices for which they are substituted.

The electrical input characteristics are the same as the squib, primer or detonator that they simulate.

Indicators are used in static firings of missiles to test the electrical circuits in the actual equipment without creating the hazard of firing the explosive device.

Indicators can be silent or noisy depending on the requirements.

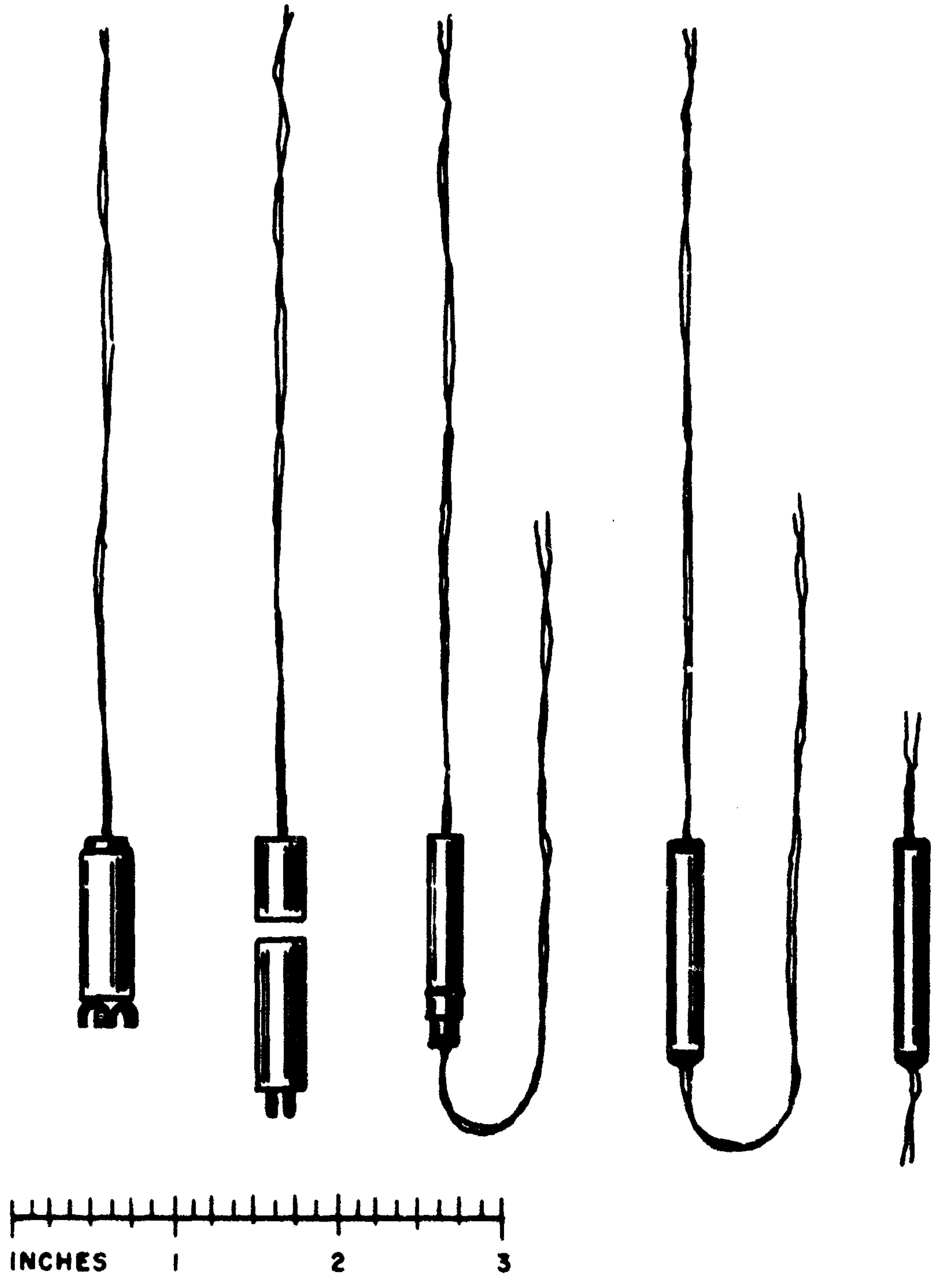



FIG. 2-18: SWITCHES (NON-EXPLOSIVE)

17. **SOFAR Bombs**

A device used to establish the location of a missile nose cone, payload or warhead at ocean impact is termed a sound fixing and ranging bomb (SOFAR). The SOFAR system came into existence with the discovery of a natural sound channel which exists in the oceans. This channel is found at depths down to 12,000 feet; however, the acoustical center or axis is generally found between 1500 and 4000 feet below the surface. The sound from a small bomb detonated near this axis can be received by monitoring stations at ranges up to 3000 miles. The monitoring or listening stations are designed to receive signals produced by underwater sound signals. Also, the various listening stations are synchronized in time, making it possible to determine the approximate location of the source of a sound signal.

The SOFAR bomb (see Figure 2-19) contains a pressure-actuated safety and arming mechanism, a detonator and an explosive charge equivalent to four (4) pounds of TNT. TNT and HBX (and modifications) are the most common explosives used in the SOFAR bombs. The SOFAR explosive train consists of a primer, detonator, tetryl lead-in and a tetryl booster. The primer and detonator are fitted into an opening on the arming piston and are not in line with the firing pin and tetryl lead-in until arming occurs. Prior to missile launching, the cotter pin on the safety and arming mechanism of the SOFAR bomb must be removed. However, the fuze of the bomb is unarmed and safe as long as the arming plunger protrudes through the diaphragm retainer. The unit is safe at an ocean depth of 750 to 1200 feet. When the bomb reaches arming depth, the hydrostatic pressure causes the arming shear pin or wire to break, allowing the arming piston to move and align the primer and detonator with the firing pin and the tetryl lead-in. At firing depth the firing shear pin is broken and water pressure forces the firing pin to strike the primer. This sets off the firing train charges in series as follows: primer, detonator, tetryl lead-in, tetryl booster, auxiliary booster and explosive charge.

The SOFAR bomb can be exploded at varying depths of 1500, 2000, 2500, 3000, 3500, 4000 feet and more.

18. **Staging Rockets**

Multiple-stage missiles are equipped with two

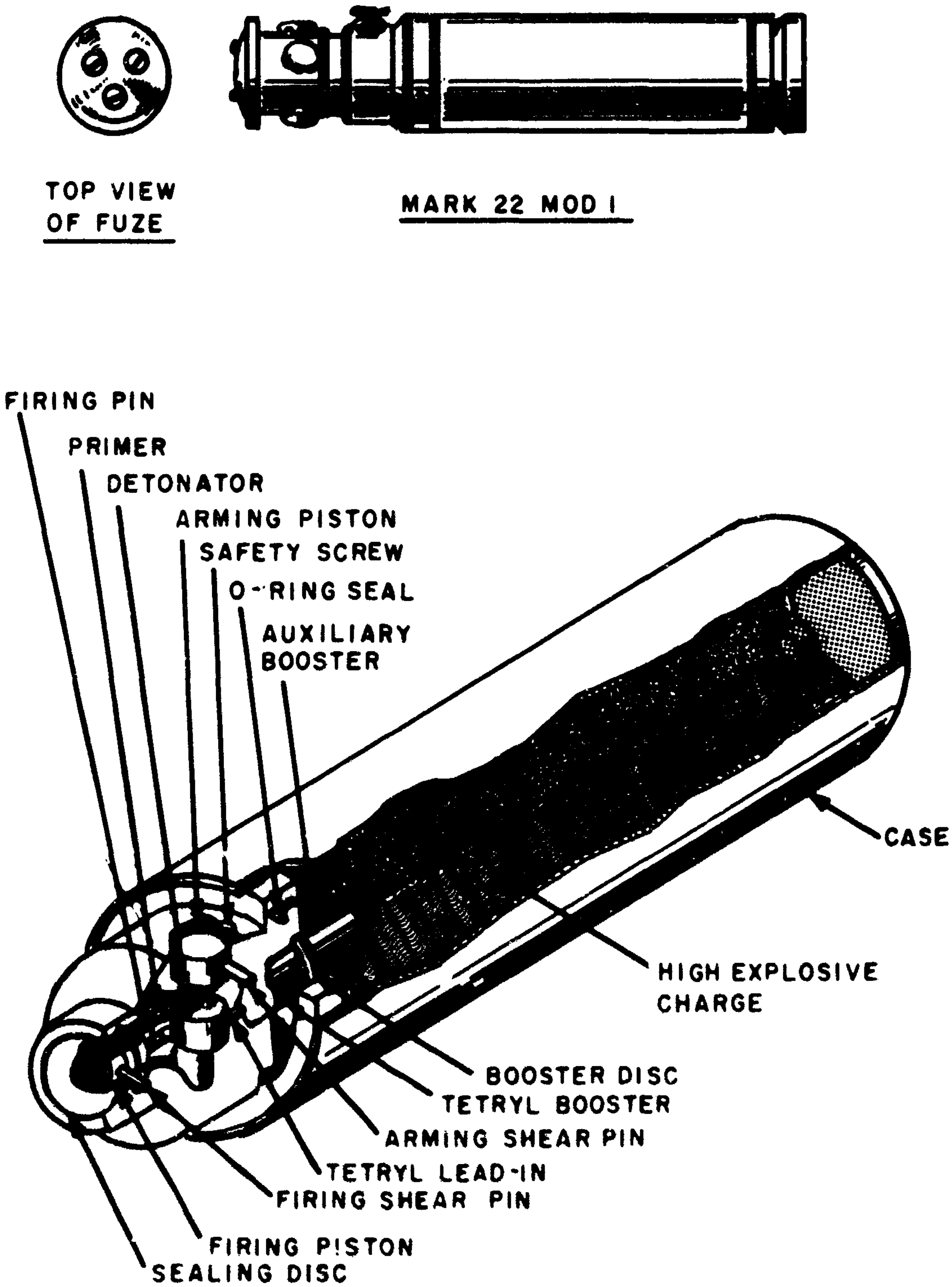



FIG. 2-19: SOFAR Bomb

or four small rockets known as "staging rockets." These small rockets are mounted at 180-degrees apart (90-degrees for four rockets) on the aft end of the missile stage that will continue in flight. These rockets burn for 2 to 5 seconds depending upon the size of the missile. The rockets deliver a combined thrust that produces a minimum separation distance (5 to 15 feet) between the burned-out stage and the continuing stage. The separation distance is obtained before ignition of the continuing stage. After burn-out the staging rockets are jettisoned by pressure squibs.

A staging rocket consists of a pressure chamber, head plate, nozzle assembly and an electrical head-end type igniter (see Figure 2-20). The propellant charge is a high-energy, solid propellant of the double-base or composite type.

19. Retro- or Retarding Rockets

Retro- or retarding rockets are rocket units, usually of the solid propellant type used to retard one body relative to another's direction. This is accomplished by retro-thrust.

Retro-rockets contain an integrally mounted igniter and are manufactured as a complete assembled unit. These rockets cannot be disassembled or repaired. The propellant is solid, either cast double-base or composite and has an auto-ignition point greater than 500°F.

These rockets are used in missiles to aid in reentry vehicle separation and separation of missile stages.

C. Hazards of Explosive-Ordnance Devices

The trend of design in explosive-ordnance devices has been to produce more sensitive explosive actuators. The quantities of energy required for initiation of explosive devices decrease as the electrical sensitivity increases. This fact allows very small batteries to be used as power sources to initiate the explosive actuator. This trend has been impaired by mounting reports of inadvertent initiation of explosive devices by radio frequency energy, spurious signals, heat, vibration, sound, static electrical discharge, explosive discharge and nuclear radiation. These hazards are being disclosed to the designers of explosive devices and preventative measures are being effected to eliminate these problems.

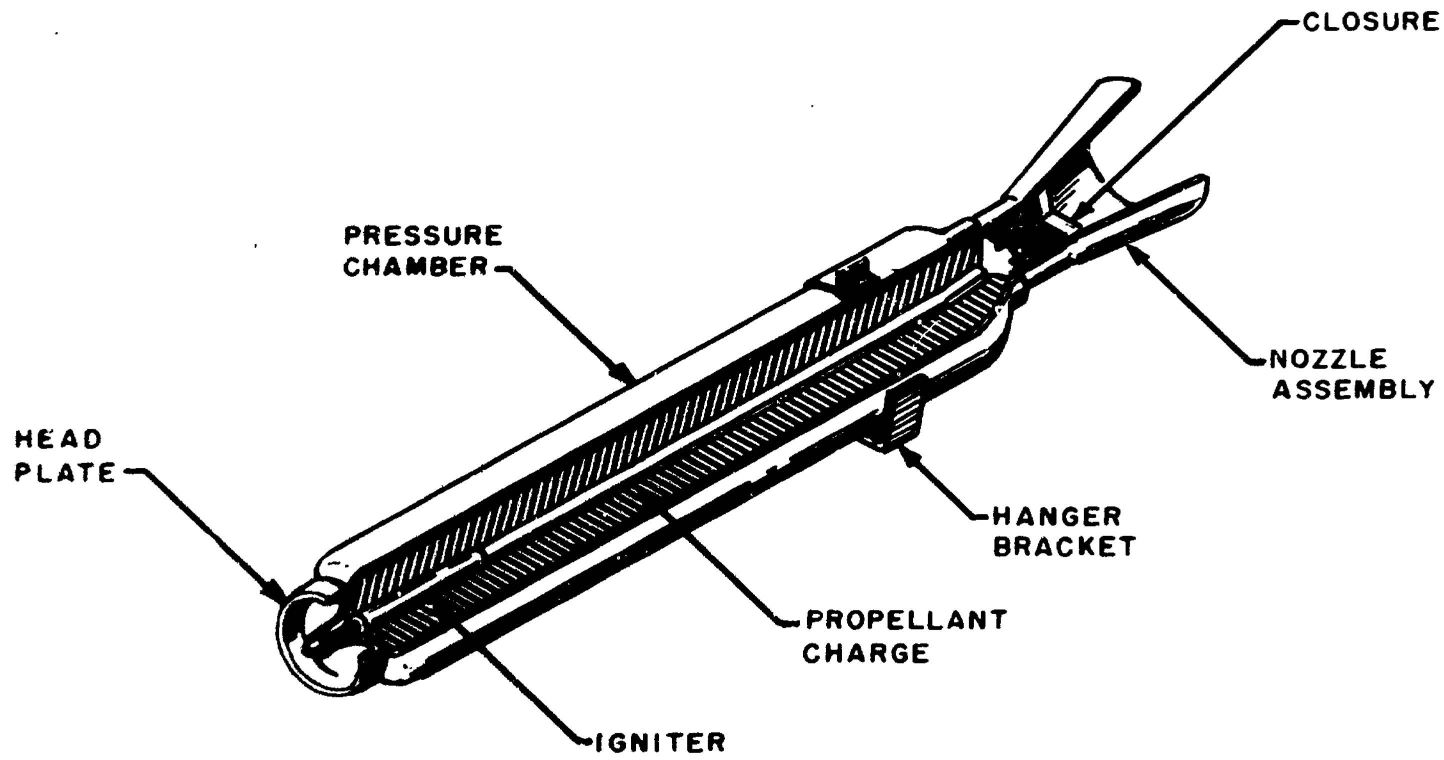



FIG. 2-20: STAGING ROCKET

## IX. ROCKETS AND ROCKET MOTORS

### A. General

A rocket may be defined as a craft or missile that obtains its operating power or thrust from the energy of the propellants confined or stored within its walls. The operating power or thrust is obtained by the ejection of hot gases generated by the chemical reaction between the fuel and oxidizer within the combustion chamber of the rocket-thrust motor.

Chemical reactions occur at a rapid rate in a rocket-thrust combustion chamber. The rapid rate of reaction results in a high temperature, pressure and thrust and it is necessary to control the reaction to attain a longer period of reaction.

Rockets and rocket motors utilize the principle of jet propulsion. This is based on Newton's Third Law that states "action and reaction are equal and opposite." If a gas or fluid is ejected from a closed-end vessel through a constricted area (nozzle) at high velocity, then the force causing its ejection results in an equal force in the opposite direction. The force produced by the hot ejected gases propels the vessel in the opposite direction of the emitting fluid or gas.

The basic principles involved in the action of any jet propulsion unit may also apply to any rocket and rocket motor.

### B. Classification of Rockets and Rocket Motors

The physical state of the propellant used in a rocket system assists in classifying the rocket and rocket motor as solid or liquid.

A solid propellant rocket and rocket motor is characterized by its short burning time, simple design, heavy construction and non-intermittent operation. At present, the design for solid rockets is undergoing change from heavy construction to light-weight and heat-resistant materials. Methods to produce solid rockets and rocket motors with built-in intermittent operation have been developed and although not completely operational at this writing, will undoubtedly increase the use of solid propellant rockets in the future.

The liquid propellant rocket unit is usually a longer-burning unit, relatively complicated in design and operation and has intermittent operation possibilities.

This MANUAL will discuss only the solid propellant rocket and rocket motor.

C. Solid Propellant Rockets

A solid propellant rocket unit consists of the propellant, combustion chamber, igniter and exhaust nozzle. The components of a solid propellant rocket are shown in Figure 2-21. The combustion chamber and exhaust nozzle will be discussed in detail. The propellant and igniter have been discussed previously in this Section.

1. Combustion Chamber

The combustion chamber of a solid propellant rocket serves two (2) purposes. First, it acts as a storage cell for the propellant and secondly, it acts as a combustion chamber for the burning of the propellant. Depending upon the solid propellant grain configuration used, this chamber may also contain a device for holding the grain in the desired position (exceptions are the cast-in-case composite propellants). A trap is used to prevent flying particles (slivers) of the propellant from clogging the throat area of the exhaust nozzle. Also, resonance rods are installed for the purpose of absorbing vibrations caused in the chamber by the rapid reaction of the burning propellant.

The critical factors considered in the design of a combustion chamber for solid propellant rockets are:

a. Sufficient material strength to withstand the internal pressures at extremely high temperatures.

b. Mechanical provisions for attaching the nozzle or nozzle assembly and the head- or front-end assembly.

c. The type of burning exhibited by the propellant grain. Steel is required for chambers exposed to hot gases. Light-weight aluminum may be used when the interior chamber wall is protected by case bonding, plastic coatings, flame-proofing materials and encased propellants.

d. Rigid specifications are required for high performance rockets. Material strength must have very little variation. Uniformity of wall thickness and concentricity must be carefully controlled. Axial alignment must be held to a close tolerance.

2. Exhaust Nozzle

An exhaust nozzle is a non-uniform chamber through

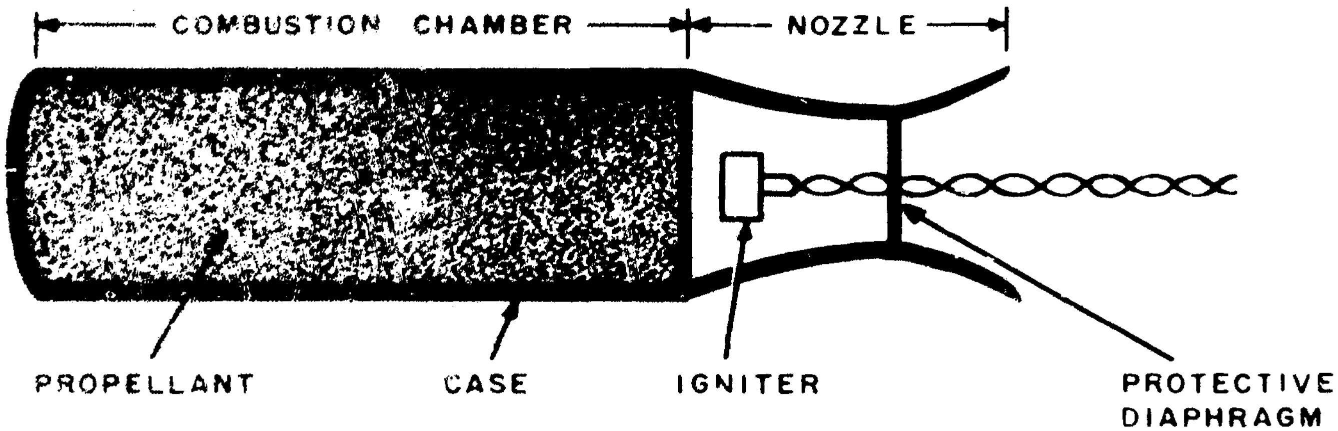



FIG. 2-21· COMPONENTS OF A SOLID ROCKET MOTOR

which the gases generated in the combustion chamber flow to the outside. In the nozzle, the most important areas considered in design are the cross-sections at the mouth, the throat and the exit. These areas are illustrated in Figure 2-22A.

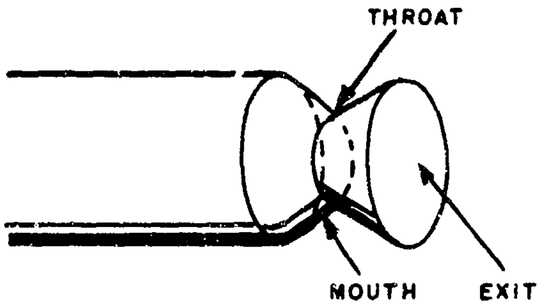
The function of a nozzle is to increase the velocity of the gases. Under steady flow conditions, the weight of the gases that pass any cross-section in unit time is constant (Bernoulli's Theorem). When the gas-flow is less than the speed of sound (subsonic), the velocity of the gases must increase if the cross-section is constricted at some point and the weight rate of flow stays constant. As the cross-section becomes wider the velocity of the gases decreases. This relation of cross-section to velocity holds true for subsonic flow of gases. However, it is not true for gases flowing at speeds greater than sound (supersonic).

The velocity of subsonic gases passing through a convergent nozzle, as illustrated in Figure 2-22B, will continue to increase until it reaches the local speed of sound or Mach 1 (the speed of sound corresponding to the temperature at a specific point in the exhaust nozzle).

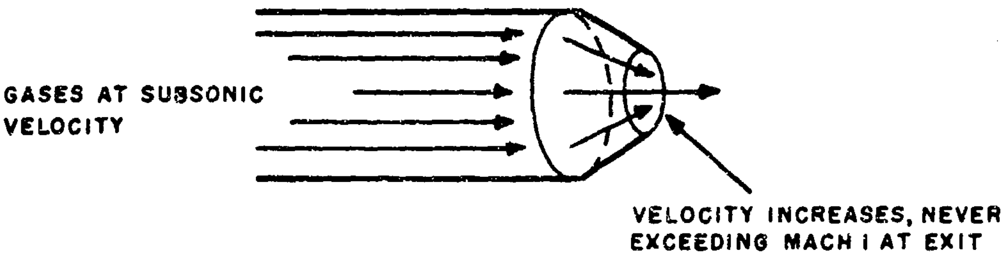
The gas-flow at supersonic velocities decreases when passing through a convergent-type nozzle.

The illustration in Figure 2-22C indicates that supersonic flow increases when passing through a divergent-type nozzle. Subsonic flow decreases when passing through a divergent nozzle. This decrease is consistent with Bernoulli's Theorem. The velocity of the gas flow must decrease with a proportionate increase in pressure because the cross-section increases and the weight rate of flow remains constant. Again, this is not the case with supersonic flow because the gases are in a compressed state. As the nozzle diverges the gases expand and the pent-up pressure is then converted to kinetic energy. This increases the velocity of the gases.

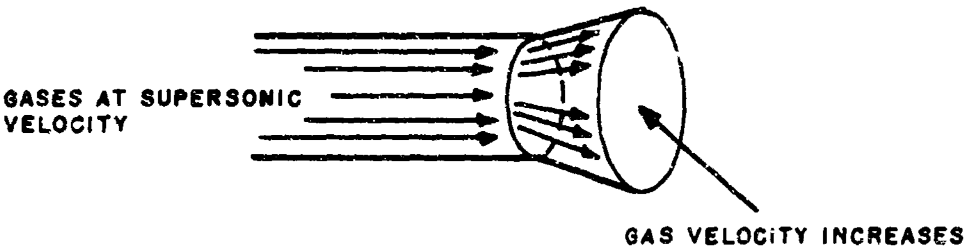
Present-day rocket motors combine the convergent and divergent shapes in the exhaust nozzle for the purpose of obtaining supersonic exhaust velocity. This is illustrated in Figure 2-22D. The convergence of the exhaust nozzle increases the subsonic flow of gases up to the local speed of sound. And then, due to critical design, the nozzle diverges, allowing for gas expansion. This gas expansion produces supersonic flow.



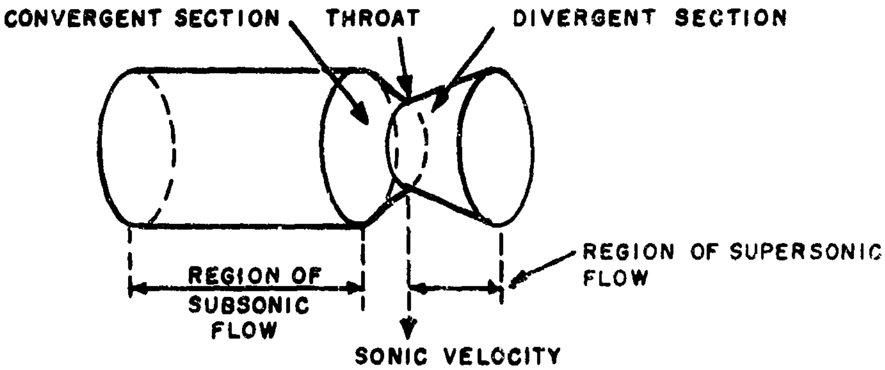

A. NOZZLE COMPONENTS




B. SUBSONIC FLOW THROUGH A CONVERGENT NOZZLE




C. SUPERSONIC FLOW THROUGH A DIVERGENT NOZZLE




D. CONVERGENT - DIVERGENT NOZZLE

FIG. 2-22: ROCKET MOTOR NOZZLES

Rockets and rocket motors of the present missile systems employ the convergent-type nozzle or the convergent-divergent (DeLaval) nozzle.

The convergent-type nozzle is constructed for a specific set of propellant and combustion characteristics in order to obtain the highest practical exhaust velocity.

The convergent-divergent nozzle is used to control the expansion of the gases after they pass through the throat of the nozzle. A higher velocity and an increase in thrust is obtained. The area of the throat is determined by the weight rate of the gas flow required. The area at the exit of the divergent section is determined by the ratio of expansion required for the gases between the throat and the exit.

Since requirements have become more stringent the nozzle designs have undergone a number of specific changes. However, the general configuration has not changed. A constant need for reduction in total rocket weight has necessarily caused a thinning of the nozzle body. Nozzle surface erosion caused by extreme and instantaneous heat transfers has always been a serious problem for the rocket designers.

Copper or steel nozzles with molybdenum inserts have proven highly effective in erosion prevention for homogeneous or double-base propellant rockets. Carbon inserts have functioned reasonably well for the composite or heterogeneous propellant rockets. However, the development of new ceramic liners has alleviated many of the erosion problems in nozzle design.

D. Types of Rockets and Rocket Motors

Many types of rockets and rocket motors have been developed for use in the missile weapons system. These rockets range in weight from several pounds to many tons. They vary in length from several inches to fifty feet and the outside diameters from inches to eight or ten feet. The thrust and specific impulse will vary according to the types of propellants utilized. Also, they are designed to perform many different functions. In most cases the name of the rocket indicates the type of rocket performance. Examples are booster rockets, JATO (Jet Assisted Take-Off) rockets, RATO (Rocket Assisted Take-Off) rockets, vernier rockets, retro-rockets, retarding rockets, sustainer rockets, ejection rockets, spin rockets, artillery rockets, etcetera. The types or propellants used in these various rockets are discussed in Subsection IV - Solid Propellants.

## X. ROCKET ACCESSORIES

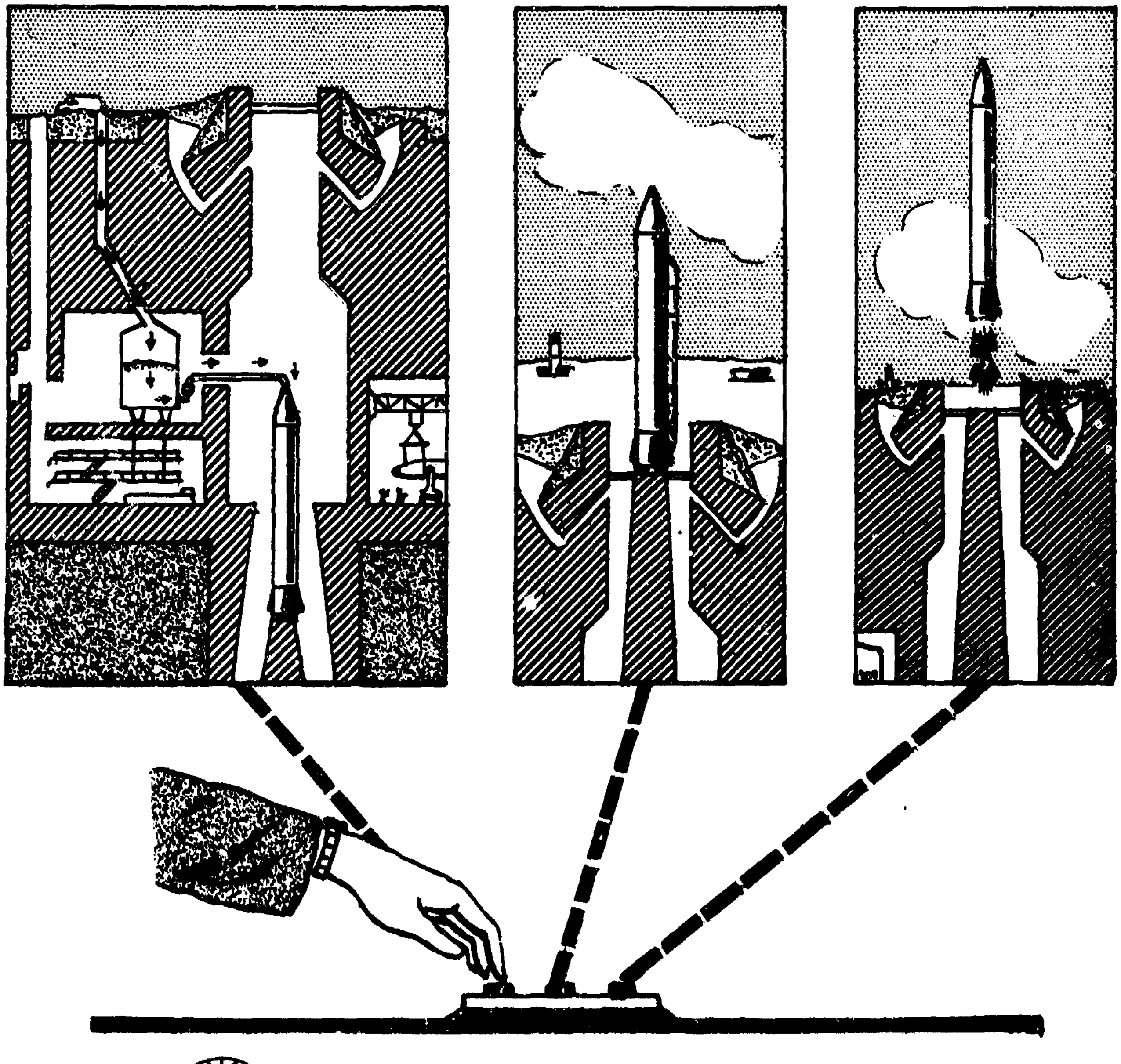
Many rocket units incorporate a safety diaphragm for escape of excessive gases and a deflector cap to direct the gases down-stream from the diaphragm.

A bursting diaphragm, together with an electrically operated blow-off charge may be used to stop the operation or burning of a solid propellant rocket. This action may be accomplished in one of two ways. The nozzle area opened by the bursting diaphragm lowers the chamber pressure sufficiently to prevent continuous active high-thrust combustion. The other method is to locate the bursting diaphragm at a point in the rocket motor in order that it will nullify the thrust produced by the regular exhaust nozzle (changes the gas flow in opposite direction).

Other accessories for rocket motors include:

1. Handling hooks
2. Means for loading or replacing the propellant charge
3. Brackets for upright storage
4. Brackets for mounting rocket motors in vehicles
5. Moisture seals
6. Protective-dust caps
7. Provisions for mounting the propellant grain in the chamber
8. Inspection parts.

# GENERAL REVIEW IN THE ART OF HANDLING MISSILE PROPELLANTS



PAN AMERICAN WORLD AIRWAYS
GUIDED MISSILES RANGE DIVISION
PATRICK AIR FORCE BASE, FLORIDA

# GENERAL REVIEW IN THE ART OF HANDLING MISSILE PROPELLANTS

The preceding Sections of this MANUAL were devoted to a discussion of explosives, ammunition and solid propellants, which include materials utilized in present day missile propellant systems. Regulations and instructions for storing, shipping, handling, inspecting, testing, overhauling and preserving specific missiles are covered in publications of higher security classification. Information relative to the safety precautions and methods of fire fighting where missiles and their major components are involved are also covered in regulations and instructions written for specific missiles.

Since 1954, the applications of solid propellant rockets have expanded from small rocket motors of several hundred pounds to large rocket motors of 20 to 30 tons or more. New methods of processing have been developed that may provide complete fabrication of large solid propellant type missiles at the launching sites. These new methods indicate less hazardous handling and simpler and more compatible storage, resulting in safer operations.

The reliability of any missile weapons systems is dependent upon the functional operations of the missile components and the operating personnel. The newer solid propellant missile systems under development are designed for increased reliability through automation. Automation presents some electromechanical complexity but reduces human participation in a number of operations. The reliability of missile weapons systems can be considerably increased with the utilization of solid propellants coupled with automation.

The handling methods and equipment of the present missile systems are rapidly becoming obsolete. The development of handling equipment is not in pace with the development of the newer missile systems. The advent of automation should simplify handling problems and eliminate many of the hazards that confront personnel exposed to the rigors of present handling procedures.

Chemical advances will possibly increase the stability and compatibility of solid propellants to the extent that present storage problems of compatibility, quantity distance, corrosion protection, etcetera will be kept to a minimum. Also, high cost and heavily constructed storage buildings may be eliminated.

Materials can always be replaced but personnel cannot. Until the day that complete automation is provided for handling missile weapon systems, the safety of operating personnel must receive prime consideration. Safety must remain an integral part of all future propellant systems developments and operations so that the maximum possible safety precautions for operating personnel will always be provided.

PAN AMERICAN WORLD AIRWAYS
GUIDED MISSILES RANGE DIVISION
PATRICK AIR FORCE BASE, FLORIDA



# BIBLIOGRAPHY

# BIBLIOGRAPHY

The following list of Armed Services publications and books contains data that pertains to the characteristics, properties, handling, transportation, storage and safety of explosives, ammunition and solid propellants. The publications were used as reference material in the preparation of the "MANUAL FOR HANDLING EXPLOSIVES, AMMUNITION AND SOLID PROPELLANTS."

<u>Armed Services Publications</u>


1. ORD M7-224/T.O. 11A-1-40 Ordnance Safety Manual, 1951 (Changes 1-7, 1951-1959).

2. Air Munition Letters, Ogden Air Materiel Area, United States Air Force, Hill Air Force Base, Utah.

3. TM 9-1900/T.O. 11A-1-20 Ammunition General, 1956.

4. TM 9-1905 Ammunition Renovation, 1948.

5. TM 9-1910/T.O. 11A-1-34 Military Explosives, 1955.

6. TM 3-215/T.O. 39C-5-18 Military Chemistry and Chemical Agents, 1952.

7. T.O. 11C2-1-1 Chemical Bombs and Clusters.

8. TM 9-1903/T.O. 11A-1-37 Care, Handling, Preservation and Destruction of Ammunition, October, 1956.

9. T.O. 00-85-13 Handbook-Transportation, Packaging and Handling Dangerous Materials for Military Airlift, June 2, 1958 (Revised).

10. T.O. 11C-1-6 General Safety Procedures for Chemical Guided Missile Propellants, December 12, 1956.

11. FM 5-25 Explosives and Demolition.

12. Liquid Propellant Safety Manual, October, 1958. Liquid Propellants Information Agency, Applied Physics Laboratory, Johns Hopkins University, Silver Spring, Maryland.

13. OP 5 (Volume 1, 2nd Revision) Ammunition Ashore, Handling, Stowing and Shipping, U. S. Navy, Bureau of Ordnance, August 9, 1957.

14. OP 2213 Pyrotechnics and Miscellaneous Explosive Items, U. S. Navy, Bureau of Ordnance, December 31, 1957.

15. Code of Federal Regulations, Title 46-Shipping Subchapter N-Explosives or Other Dangerous Articles or Substances and Combustible Liquids on Board Vessels, Parts 146, 147, 148 and 149, Government Printing Office, Washington 25, D. C., 1959.

16. TM 9-1950/T.O. 11A-11-1-101 Rockets, 1950.

17. TM-1946 Demolition Materials, 1955.

18. Thursby, D. E., Electroexplosive Devices, Headquarters, Air Force Special Weapons Center, ARDC, Kirtland Air Force Base, New Mexico, January, 1959.

19. TM 9-1955 JATOS, General, Dept. of the Army, September, 1955.

20. AF Manual 52-31 Guided Missiles Fundamentals, Department of the Air Force, September 20, 1957.

Books

1. Zaehringer, Alfred J., Solid Propellant Rockets, Second Stage, American Rocket Co., Box 1112, Wyandotte, Mich., 1958.

2. Warren, F. A., Rocket Propellants, Reinhold Publishing Corporation, New York, N. Y., 1958.

3. Sax, I. N., Handbook of Dangerous Materials, Reinhold Publishing Corporation, New York, N. Y., 1951.

4. Sax, I. N., Dangerous Properties of Industrial Materials, Reinhold Publishing Corporation, New York, N. Y., 1957.

5. Merrill, G., Principles of Guided Missile Design, D. Van Nostrand Company, Inc., Princeton, N. J., February, 1958.

6. Cook, M. A., The Science of High Explosives, Monograph Series, American Chemical Society, No. 139, Reinhold Publishing Co., New York, N. Y., 1958.

7. Davis, T. L., Chemistry of Powder and Explosives, one volume, John Wiley & Sons, Inc., New York, 4th printing, May, 1956.

8. Sutton, G. P., Rocket Propulsion Elements, 2nd Edition, John Wiley & Sons, Inc., New York, March, 1958.

9. Wimpress, R. N., Internal Ballistics of Solid-Fuel Rockets, 1st Edition, McGraw-Hill Book Co., Inc., New York, 1950.

10. Dictionary of Guided Missile Terms, Public Affairs Press, Washington, D. C., 1949.

11. The Condensed Chemical Dictionary, Fifth Edition, Reinhold Publishing Corp., New York, 1956.

12. Hercules Handbook, Initiators, Explosive Actuators, Non-Explosive Actuators, Gas Generators, Igniters. Explosives Department, Hercules Powder Co., Wilmington, Del., October, 1958, Revised.

13. Blasters Handbook, 14th Edition, E. I. DuPont de Nemours & Co., Inc., Wilmington, Del., 1958.

14. Bebie, Jules, Manual of Explosives, Military Pyrotechnics and Chemical Warfare Agents, MacMillan Company, New York, 1943.

15. Safety in the Handling and Use of Explosives, Institute of Makers of Explosives, New York, 1951.

16. Motor Carriers' Explosives and Dangerous Articles Tariff No. 9 (Interstate Commerce Commission Regulations for the Transportation of Explosives and Other Dangerous Articles), Effective February 1, 1957.

17. Taylor, James, Solid Propellent and Exothermic Compositions, Interscience Publishers, Inc., New York, N. Y., 1959.

18. The American Table of Distances, Institute of Makers of Explosives, Pamphlet No. 2, New York, N. Y., 1955.